Quality Assurance Project Plan

Remedial Investigation/Feasibility Study

Falcon Refinery Superfund Site
Ingleside, San Patricio County, Texas
EPA Identification No. TXD086278058

Remedial Action Contract 2 Full Service
Contract: EP-W-06-004
Task Order: 0088-RICO-06MC

Prepared for

U.S. Environmental Protection Agency
Region 6
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4 February 2013

Tim Startz, PMP | Date
EA Program Manager

4 February 2013

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LIST OF ACRONYMS AND ABBREVIATIONS

95UCLM	95% Upper Confidence Limit of the Mean
ADSM	Alternatives Development and Screening Memorandum
AOC	Area of Concern
bgs	Below ground surface
BTV	Background level threshold values
CFR	Code of Federal Regulations
CLP	Contract Laboratory Program
COPC	Contaminant of potential concern
CRDL	Contract-required Detection Limit
CRQL	Contract-required Quantitation Limit
CSM	Conceptual Site Model
DESR	Data Evaluation Summary Report
DMA	Demonstration of Methods Applicability
DQO	Data quality objective
EA	EA Engineering, Science, and Technology, Inc.
EDD	Electronic data deliverable
EPA	U.S. Environmental Protection Agency
ERA	Ecological risk assessment
FS	Feasibility Study
FSP	Field Sampling Plan
ft	foot
H_o	Null hypothesis
H_a	Alternative hypothesis
HHRA	Human health risk assessment
HRS	Hazard Ranking System
HSP	Health and Safety Plan
IDW	Investigation-derived waste
LCS	Laboratory control spike
MCL	Maximum contaminant level
MD	Matrix duplicate
MDL	Method detection limit
MS	Matrix spike

MSD	Matrix spike duplicate
NORCO	National Oil Recovery Corporation
OU	Operational Unit
OS	Original sample
OSHA	Occupational Safety and Health Administration
PARCC	Precision, accuracy, representativeness, completeness, and comparability
PCB	Polychlorinated biphenyl
PCL	Protective concentration levels
PID	Photoionization detector
PSQ	Principal study question
QA	Quality assurance
QAPP	Quality Assurance Project Plan
QC	Quality control
RAC	Remedial Action Contract
RACA	Remedial Alternatives Comparative Analysis
RAGS	Risk Assessment Guidance for Superfund
RAO	Remedial action objective
RBEL	Risk-based exposure limits
RI	Remedial Investigation
ROD	Record of Decision
RPD	Relative percent difference
RSL	Regional screening levels
Site	Falcon Refinery Superfund Site
SMP	Site Management Plan
SOP	Standard operating procedure
SOW	Statement of Work
SPLP	Synthetic Precipitation Leaching Procedure
SSL	Soil screening levels
SVOC	Semi-volatile organic compound
TCEQ	Texas Commission on Environmental Quality
TCLP	Toxicity Characteristic Leaching Procedure
TOM	Task Order Monitor
TRC	TRC Environmental Corporation
TRRP	Texas Risk Reduction Program
TSS	Total suspended solids
VOC	Volatile organic compound
VSP	Visual Sample Plan

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1. PROJECT DESCRIPTION AND MANAGEMENT

EA Engineering, Science, and Technology, Inc. (EA) has been authorized by the U.S. Environmental Protection Agency (EPA), under Remedial Action Contract (RAC) Number EP-W-06-004, Task Order 0088-RICO-06MC, to conduct a Remedial Investigation/Feasibility Study (RI/FS) at the Falcon Refinery Superfund Site (site). EA has prepared this Quality Assurance Project Plan (QAPP) in accordance with:

(1) Specifications provided in the EPA Statement of Work (SOW), dated 3 February 2012 (EPA 2012a)

(2) The EPA-approved EA Work Plan (Revision 01), dated 24 April 2012 (EA 2012a)

(3) EA's Quality Management Plan (EA 2012b).

This QAPP was prepared in conjunction with the Field Sampling Plan (FSP) (EA 2012c). The QAPP documents the planning, implementation, and assessment procedures, as well as specific quality assurance (QA) and quality control (QC) activities. The FSP details the field sampling schedule, rationales for sample selection, and sampling methods required to perform an RI/FS. Together, the QAPP and FSP present the overall approach for implementing the RI/FS field program.

This QAPP meets requirements set forth in EPA Requirements for Quality Assurance Project Plans for Environmental Data Operation (QA/R-5) (EPA 2001a) and Guidance for Quality Assurance Project Plans (QA/G-5) (EPA 2002a).

This QAPP describes procedures to assure that the project-specific data quality objectives (DQOs) are met, and that the quality of data (represented by precision, accuracy, completeness, comparability, representativeness, and sensitivity) is known and documented. The QAPP presents the project description, project organization and responsibilities, and QA objectives associated with the sampling and analytical services to be provided in support of the RI/FS. Table 1 demonstrates how this QAPP complies with elements of a QAPP currently required by EPA guidance (EPA 2001a, 2002a).

The overall QA objectives are as follows:

- Attain QC requirements for analyses specified in this QAPP
- Obtain data of known quality to support goals set forth for this project
- Document aspects of the quality program including performance of the work and required changes to work at the site.

TABLE 1 ELEMENTS OF EPA QA/R-5 IN RELATION TO THIS QAPP

EPA QA/R-5 QAPP Element	EA QAPP
A1 Title and Approval Sheet	Title and Approval Sheet
A2 Table of Contents	Table of Contents
A3 Distribution List	Distribution List
A4 Project/Task Organization	1.0 Project Description and Management
A5 Problem Definition/Background	1.1 Problem Definition and Background
A6 Project/Task Description	1.2 Description of Project Objectives and Tasks
A7 Quality Objectives and Criteria	1.3 Data Quality Objectives 1.4 Quality Assurance Objectives for Measurement Data
A8 Special Training/Certification	1.5 Special Training and Certification
A9 Documents and Records	1.6 Documents and Records
B1 Sampling Process Design	2.1 Sampling Process Design
B2 Sampling Methods	2.2 Sampling Methodology
B3 Sample Handling and Custody	2.5 Sample Container, Volume, Preservation, and Holding Time Requirements 2.6 Sample Handling and Custody
B4 Analytical Methods	2.7 Analytical Methods Requirements
B5 Quality Control	2.8 Quality Control Requirements
B6 Instrument/Equipment Testing, Inspection, and Maintenance	2.9 Instrument and Equipment Testing, Inspection, and Maintenance Requirements
B7 Instrument/Equipment Calibration and Frequency	2.9 Instrument Calibration and Frequency
B8 Inspection/Acceptance of Supplies and Consumables	2.10 Requirements for Inspection and Acceptance of Supplies and Consumables
B9 Non-direct Measurements	2.11 Data Acquisition Requirements (Non-Direct Measurements)
B10 Data Management	2.12 Data Management
C1 Assessment and Response Actions	3.1 Assessment and Response Actions
C2 Reports to Management	3.2 Reports to Management
D1 Data Review, Verification, and Validation	4.1 Data Review and Reduction Requirements
D2 Validation and Verification Methods	4.2 Validation and Verification Methods
D3 Reconciliation with User Requirements	4.3 Reconciliation with Data Quality Objectives

The EPA Region 6 Task Order Monitor (TOM), Mr. Brian Mueller, is responsible for the project oversight. The Project Officer for EPA Region 6 is Ms. Rena McClurg. The Contracting Officer for EPA Region 6 is Mr. Michael Pheeny. EA will perform tasks under this Task Order in accordance with this QAPP. The EA Project Manager, Mr. Robert Owens, is responsible for implementing activities required by this Task Order. The EA QA Officer, Mr. David Santoro, provides an independent evaluator of the data collection process. Figure 1 presents the proposed project organization for this Task Order.

1.1 PROBLEM DEFINITION AND BACKGROUND

This purpose of the investigation and sampling events is provided in Section 1.1.1. The site background and description is presented in Section 1.1.2. The EPA Removal Action is presented in Section 1.1.3. The site listing on the National Priorities List is detailed in Section 1.1.4.

1.1.1 Purpose of the Investigation and Sampling Events

Phase I of the RI was performed by Kleinfelder on behalf of the National Oil Recovery Corporation (NORCO) in 2007. The number of soil, sediment, ground water, and surface water judgmental or random grid locations sampled during Phase I were initially determined by the site team and were not based on the distribution of constituents, if any, at the site. Phase I helped to determine the distribution of constituents at the site and develop a Conceptual Site Model (CSM), presented in Section 1.3.2.3.

The data from Phase I was analyzed and the standard deviation, alpha and beta error rates, width of the gray region, and a threshold value (screening value) were input into Visual Sample Plan (VSP) software algorithms to statistically determine the minimum number of samples required to meet the DQOs for the site. This analysis served as the basis for the Field Sampling Plan Addendum No. 1a (TRC Environmental Corporation [TRC] 2011), prepared by TRC on behalf of NORCO for Phase II sampling.

The TRC Field Sampling Plan Addendum No. 1a (TRC 2011) and the Quality Assurance Project Plan Addendum No. 01 by Kleinfelder (2009a) serve as references for this QAPP. The Phase I investigation results and conclusions and the CSM presented in this QAPP are taken from these reference documents and further evaluated by EA.

The purpose of this investigation is to collect Phase II ground water, surface water, surface and subsurface soils, and sediment data to support an RI/FS. The RI/FS process will allow the EPA to select a remedy that eliminates, reduces, or controls risks to human health and the environment. The goal is to develop the minimum amount of data necessary to support a Record of Decision (ROD). The EPA RI/FS SOW (EPA 2012a) and EPA-approved Work Plan (EA 2012a) sets forth the framework and requirements for this effort.

1.1.2 Site Background and Description

The site is located 1.7 miles southeast of State Highway 361 on FM 2725 at the north and south corners of the intersection of FM 2725 and Bishop Road near the City of Ingleside in San Patricio County, Texas (Figure 2). The site occupies approximately 104 acres and consists of a refinery that operated intermittently and has not produced hydrocarbon products in several years. The refinery is currently inactive, except for a crude oil storage operation being conducted by Superior Crude Gathering, Inc. When in operation the refinery had a capacity of 40,000 barrels per day and the primary products consisted of naphtha, jet fuel, kerosene, diesel, and fuel oil. The refinery also historically transferred and stored vinyl acetate, a substance not excluded under the petroleum exclusion.

Surface water drainage from the site enters wetlands along the southeastern section of the abandoned refinery. The wetlands connect to the Intracoastal Waterway and Redfish Bay, which connects Corpus Christi Bay to the Gulf of Mexico. The site is bordered by wetlands to the northeast and southeast, residential areas to the north and northwest, Plains Marketing L.P. (a crude oil storage facility) to the north, and several construction companies to the west and south. Other portions of the site include above-ground and buried piping leading from the site to dock facilities, owned by NORCO, at Redfish Bay.

1.1.3 EPA Removal Action

The potentially responsible party (PRP) for the site, NORCO, entered into an Administrative Order on Consent with EPA, on 9 June 2004. The PRP agreed to perform and finance the Removal Action and RI/FS for the site. The purpose of the Removal Action was to address the wastes from the abandoned tanks, equipment, and piping. The Removal Action currently is ongoing. EPA approved the PRP's RI/FS Work Plan, Field Sampling Plan, and Quality Assurance Project Plan on 22 October 2007; and Addendum 1 on 8 May 2009.

On 16 February 2010, in response to EPA's 2009 request for reimbursement of the RI/FS Special Account under the terms of the Administrative Order on Consent, NORCO notified EPA that it was financially unable to perform the remaining RI/FS work. On 28 March 2011, EPA notified NORCO of the takeover of the performance of the remaining work under the Administrative Order on Consent for the RI/FS. EPA invoked the takeover because NORCO failed to comply with the terms and conditions. On 16 December 2011, after providing NORCO another opportunity to resume the remaining work under the terms of the Administrative Order on Consent and an Agreed Order for Resumption (Agreed Order) of RI/FS Work, EPA again notified NORCO of the takeover of the performance of the remaining work for the RI/FS for failure to comply with the terms and conditions of the Administrative Order on Consent and Agreed Order.

1.1.4 National Priority List

The National Priorities List (NPL) is a list of national priorities among the known or threatened releases of hazardous substances, pollutants, or contaminants throughout the United States. The NPL is intended primarily to guide the EPA in determining which sites warrant further investigation to assess the nature and extent of public health and environmental risks associated with a release of hazardous substances.

The site was proposed to the NPL on 5 September 2002. The final listing was deferred at the time, since the PRP agreed to enter into an Administrative Order on Consent for the RI/FS with the EPA, and the site was initially identified as an "alternative site." The site was listed as final after the PRP failed to comply with the terms and conditions of the Administrative Order on Consent. The final listing date is 16 September 2011.

1.2 DESCRIPTION OF PROJECT OBJECTIVES AND TASKS

This section describes the project objectives and tasks for this QAPP.

1.2.1 Project Objectives

The primary objectives of the Phase II RI/FS are to determine the nature and extent of contamination, to identify contamination migration pathways, and to gather sufficient information so that the EPA can select a remedy that eliminates, reduces, or controls risks to human health and the environment. Data must be of sufficient quality and quantity to perform an ecological risk assessment (ERA) and human health risk assessment (HHRA) for the site. Specifically, the Phase II RI involves multimedia environmental sampling of the site. EA will implement the following key components during the RI/FS:

- **Monitor Well Installation**

  - Up to 17 permanent monitoring wells will be installed and developed to evaluate potential impacts to ground water. The average depth of each of the permanent wells is estimated to be approximately 15 feet (ft) below ground surface (bgs).
  - Up to 10 temporary monitoring wells will be installed and developed to evaluate background ground water. The average depth of each of the temporary wells is estimated to be approximately 15 ft bgs.
  - Slug tests will be performed in one or 2 of the permanent monitor wells to characterize aquifer characteristics.
  - The top of casing elevations will be surveyed.

- **Soil Sampling**

  - Onsite and offsite surface and subsurface soil sampling (up to 261 samples) will be collected from surface soil and from subsurface soil from borings installed to approximate depths to 15 ft bgs to assess potential presence of contaminants of potential concern (COPCs) of high toxicity and/or high mobility, define the nature and extent, characterize waste to allow for a disposal option evaluation in the FS, evaluate whether COPCs are migrating offsite, and develop data to be used in the ERA and HHRA.
  - Surface and subsurface soil samples will be analyzed for volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), and metals. The EPA TOM will determine the number of samples to be analyzed for polychlorinated biphenyls (PCBs) and PCB congeners based on the frequency of detection of these chemicals from previous data collected by the PRP for the Site. Twenty percent of the samples will be analyzed for herbicides/pesticides.

- **Ground Water Sampling**

  - Onsite (up to 17 samples) and offsite (up to 10 samples) ground water samples will be collected from permanent and temporary monitoring wells determine the nature and extent of ground water COPCs. Permanent and temporary monitor well data will be used in the HHRA and ERA. Data collected during the onsite ground water investigation will also be used to update the pathway and receptor analysis presented in the CSM, if necessary.
  - Filtered and unfiltered samples will be analyzed from each location.
  - Ground water samples will be analyzed for VOCs, SVOCs, and metals. The EPA TOM will determine the number of samples to be analyzed for PCBs and PCB congeners based on the frequency of detection of these chemicals from previous data collected by the PRP for the Site. Twenty percent of the samples will be analyzed for herbicides/pesticides.

- **Surface Water and Sediment Sampling**

  - Offsite wetlands, intracoastal, and background surface water (up to 63 samples) and sediment (up to 34 samples) investigation will be performed to define the nature and extent of COPCs, provide data to be used in the HHRA and ERA, and to update the pathway and receptor analysis presented in the CSMs, if necessary.
  - Sediment and surface water samples will be analyzed for VOCs, SVOCs, and metals. Surface water samples will also be analyzed for total suspended solids (TSS). The EPA TOM will determine the number of samples to be analyzed for PCBs and PCB congeners based on the frequency of detection of these chemicals from previous data collected by the PRP for the site. Twenty percent of the samples will be analyzed for herbicides/pesticides.

- **Soil Vapor Sampling**

  - Soil vapor samples will be collected from permanent and temporary monitoring well locations (up to 27 samples) to assess soil to vapor contaminant transport.
  - Samples will be analyzed for VOCs.

- **Permeability Sampling**

  - Soil matrix samples (up to 60 samples) from the vadose zone (above the water table) and the saturated zone (below the water table) will be collected to further develop the CSM and assess contaminant transport.
  - Samples will be analyzed for fraction organic content, bulk density, moisture content, specific gravity, wet sieve, and/or Atterberg limits.

- **Investigative Derived Waste Sampling**

— Aqueous and solid samples of drummed waste accumulated as a result of the field investigation will be sampled, analyzed and profiled. A full hazardous waste determination will be performed on these samples. The quantity of samples will be dependent on the amount of waste generated.

- **Ecological Characterization**

— An ecological characterization may be conducted if the previous ecological characterization is not of the quality needed for this RI/FS.
— Fish tissue samples will be collected and analyzed based on the results of the Screening Level Ecological Risk Assessment (SLERA). Samples will be analyzed for parameters as directed by EPA, but will likely include lipids, pesticides, PCBs, metals, and SVOCs.

- **Air Monitoring**

— Personal air monitoring (up to 80 samples) will be performed for the protection of workers and the public during implementation of the RI/FS activities.
— Samples will be analyzed for VOCs.

- **Data Evaluation Summary Report (DESR)**

— A DESR will be prepared and submitted, which will include the data validation reports for the collected data. The purpose of the DESR is to document and summarize the analytical data collected during the RI/FS, including data quality and usability as related to the site-specific DQOs.

- **Risk Assessment**

— An HHRA will be performed to evaluate commercial/industrial, residential, construction worker, recreational, and trespasser exposure scenarios for areas identified during this investigation, as appropriate. Areas may be further subdivided into individual exposure areas based on the historical use, presence of contaminants, potential reuse, etc. An unrestricted reuse (i.e., residential) exposure scenario will be evaluated for areas of concern (AOCs) so that a ‘no action’ alternative may be evaluated in the FS.

— An ERA will be performed to characterize and quantify, where appropriate, the current and potential ecological risks that would prevail if no further remedial action is taken. The ERA will also incorporate the ecological characterization that may be conducted as part of the field investigation.

- **RI Report**

- The RI report will accurately establish the site characteristics. Potential sources of contamination, the nature and extent of contamination, and migration pathways will be identified.

- **Alternatives Development and Screening Memorandum (ADSM)**
  - Remedial alternatives will be developed and will undergo full evaluation. The technical memorandum will establish remedial action objectives (RAOs); general response actions; screening of applicable remedial technologies; development of remedial alternatives; screening of the remedial alternatives for effectiveness, implementability, and cost; summarize the alternatives as they relate to applicable or relevant and appropriate requirements (Appendix D); and summarize the screening process in relation to RAOs.

- **Remedial Alternatives Comparative Analysis (RACA) Report**
  - A comparative analysis of the remedial alternatives developed in the ADSM will be performed based on cost, implementability, and effectiveness evaluation criteria.

- **FS Report**
  - Following screening and evaluation of the remedial alternatives, the FS report will be prepared to provide a detailed analysis of alternatives and cost-effectiveness analysis, and will include the nine criteria in the National Contingency Plan.

- **Post-RI/FS Support**
  - Technical and administrative support will be provided that is required for preparation of the Proposed Plan and ROD.

- **Project Closeout**
  - Necessary activities will be performed to close out the Task Order in accordance with contract requirements.

1.2.2 Project Tasks

To complete the RI/FS site activities, EA will perform the following tasks (with subtasks), which are generally outlined in the Task Order SOW (EPA 2012a) and detailed in Sections 2, 3, and 4 of this QAPP:

- Project planning and support
- Community involvement
- Field investigation/data acquisition
- Sample analysis

- Analytical support and data validation
- Data evaluation
- Risk assessment
- RI report preparation
- Remedial alternatives screening
- Remedial alternatives evaluation
- FS report preparation
- Post-RI/FS support
- Task Order closeout.

1.3 DATA QUALITY OBJECTIVES

The following sections present the DQOs for this project. Much of the information used to develop the DQOs was obtained from the EPA SOW (2012a), EPA-approved Work Plan and Cost Estimate (EA 2012a) and the Quality Assurance Project Plan Addendum No. 01 (Kleinfelder 2009a). This DQO assessment follows EPA's 7-step DQO process (Table 2), which is outlined in Guidance on Systematic Planning Using the Data Quality Objectives Process (QA/G-4) (EPA 2006a) and Systematic Planning: A Case Study for Hazardous Waste Site Investigations (QA/CS-1) (EPA 2006b).

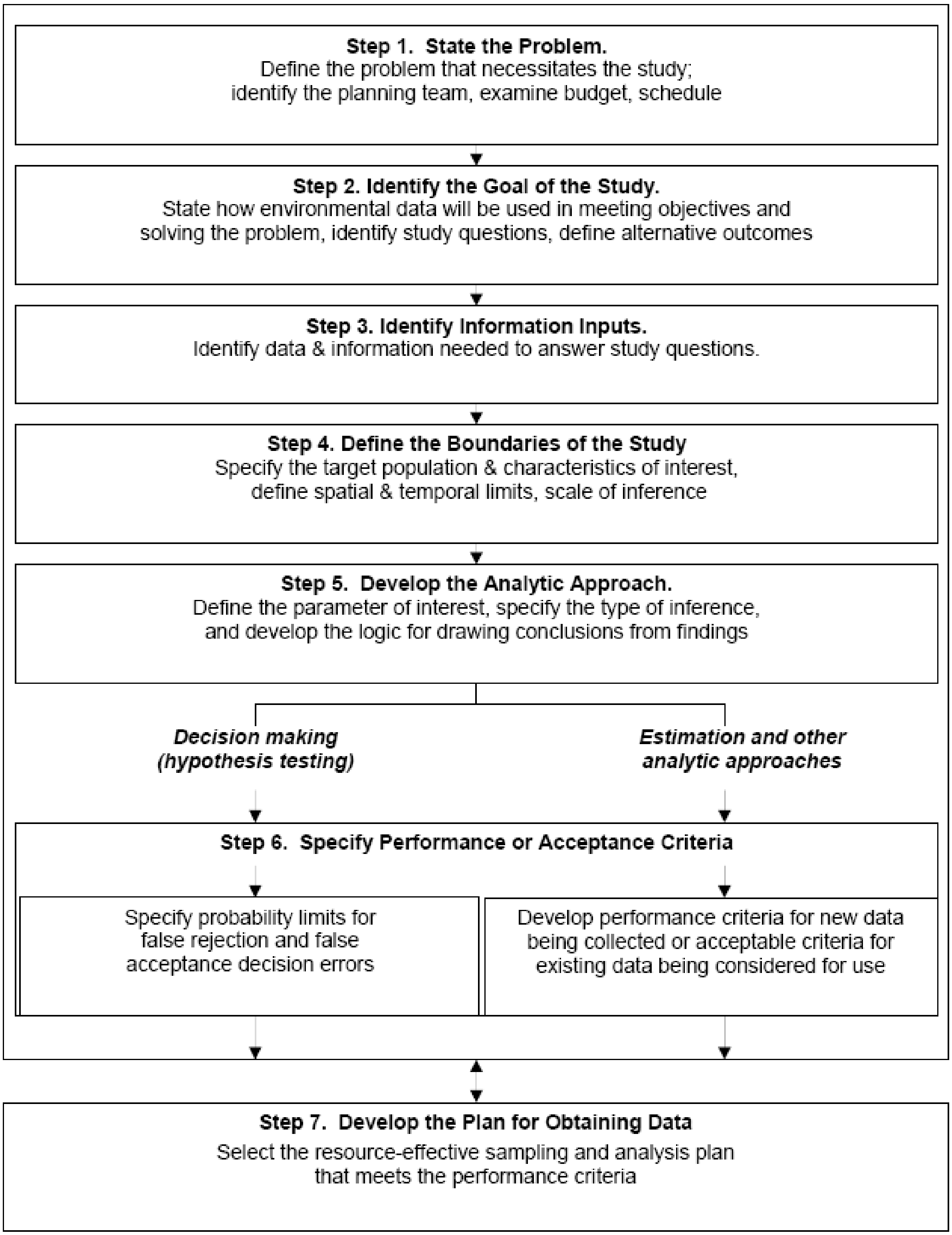
Additional information is referenced, as appropriate, in the following sections:

- Section 1.3.1 Purpose and Goal
- Section 1.3.2 Step 1 – State the Problem
- Section 1.3.3 Step 2 – Identify the Goal of the Study
- Section 1.3.4 Step 3 – Identify Information Inputs
- Section 1.3.5 Step 4 – Define the Boundaries of the Study
- Section 1.3.6 Step 5 – Develop the Analytic Approach
- Section 1.3.7 Step 6 – Specify the Performance or Acceptance Criteria
- Section 1.3.8 Step 7 – Develop the Plan for Obtaining Data.

1.3.1 Purpose and Goal

The purpose of defining the DQOs for the site is to support decision-making by applying a systematic planning and statistical hypothesis testing methodology to decide between alternatives. The goal is to develop an analytic approach and data collection strategy that is effective and efficient.

TABLE 2 DATA QUALITY OBJECTIVE PROCESS



1.3.2 Step 1 – State the Problem

The first step in systematic planning process, and therefore the DQO process, is to define the problem that has initiated the study. As environmental problems are often complex combinations of technical, economic, social, and political issues, it is critical to the success of the process to separate each problem, define it completely, and express it in an uncomplicated format.

The most important activities in DQO Step 1 are as follows:

- Give a concise description of the problem
- Identify leader and members of the planning team
- Develop a CSM for the site and potential environmental hazard to be investigated
- Determine resources (i.e., budget, personnel, and schedule).

1.3.2.1 Problem Description

Analytical results were obtained during the data collection and reporting of Phase I. Analysis of the data indicated the information gathered was not sufficient to characterize the nature and extent of all present contamination. Data collection during the RI/FS Phase II will allow assessment of human and ecological risks posed by the site. The information will then be utilized in determining an appropriate remedial response, if necessary.

1.3.2.2 Planning Team Members and Stakeholders

A proven effective approach to formulating a problem and establishing a plan for obtaining information that is necessary to resolve the problem is to involve a team of experts and stakeholders that represent a diverse, multidisciplinary background. Such a team provides the ability to develop a concise description of complex problems, and multifaceted experience and awareness of potential data uses. Planning team members (including the leader) and stakeholders are presented below.

Planning Team Members

- Brian Mueller, EPA TOM (Leader)
- Phillip Winsor, TCEQ Project Manager
- Robert Owens, EA Project Manager
- EPA Human Health Risk Assessor
- EPA Ecological Risk Assessor
- TCEQ Human Health Risk Assessor
- TCEQ Ecological Risk Assessor.

Stakeholders

- EPA Region 6 Superfund Division Management

- EPA Headquarters
- Richard Bergner, NORCO Representative Attorney
- City of Ingleside and citizenry
- State/Federal Natural Resource Trustees
- Other parties identified by EPA.

If additional planning team members and/or stakeholders are identified as the RI progresses, they will be incorporated into the decision-making process as appropriate.

1.3.2.3 Conceptual Site Model

The purpose of the CSM is to identify pathways for COPC transport and potentially impacted media and receptors. In preparing the CSM based on the Phase I investigation results, data gaps were identified in order to define the nature and extent of COPCs, conduct the ERA and HHRA, and evaluate presumptive remedies for the site. Site-specific DQOs were developed based on the CSM and were subsequently used to develop this QAPP.

EA reviewed the Phase I investigation data in preparing the CSM. However, EA has not performed any data assessment/usability evaluation of data collected from the Phase I investigation. EA assumes data collected during the Phase I investigation are usable for the purpose of identifying additional areas to assess. The data will be combined with the Phase 2 data for fate and transport and risk assessment activities. Cursory review suggests that the majority of the detection limits verses screening levels indicate the analytical methods are adequate for yielding decision-level data.

During the Phase I investigation, Kleinfelder established the nomenclature of calling source areas AOCs. This nomenclature is continued; however, the use of AOC herein is synonymous with source area or potential source area and neither means nor implies "*Area of Concern*" as defined and established by the Resource Conservation and Recovery Act (RCRA).

Seven AOC have been identified as potential areas impacted by COPCs. Three AOCs are identified onsite and four are offsite. AOCs are shown on Figure 3. Figures 4, 5, and 6 provide the preliminary human health and ecological receptor flow charts for each AOC. Each AOC is discussed in detail below.

AOC-1 Former Operational Units

AOC-1 has been subdivided into two areas that include: (1) AOC-1N, the entire north section of the refinery complex, on the northeast side of the FM 2725/Bishop Road intersection, and (2) AOC1-S, south section of the refinery complex, on the southwest side of the FM 2725/Bishop Road intersection that includes a drum disposal area and an area where metal waste was discarded.

Numerous spills and leaks have been documented in AOC-1 as summarized in the RI/FS Work Plan Volume 1 prepared by Kleinfelder in August 2007 (Kleinfelder 2007). In addition, in

February 2010 Superior Oil had a spill of crude oil from Tank 13, which pooled around Tanks 11, 12, 15, 26, 27, 28, and 30 and migrated into the wetlands in AOC-3 (Caller 2012). All areas of known releases and spills associated with AOC-1 were assessed during the Phase I Investigation, except for the following, which will be assessed as part of this investigation:

- AOC-1N – oily waste impoundment
- AOC-1S – waste pile that was located north of Tank 30 within the bermed area
- AOC-1S – oil sludge spill west of Tank 13 within the bermed area
- AOC-1S – cooling tower
- AOC-1S – Superior Oil Spill.

During the Phase I Investigation of AOC-1, soil and ground water were assessed for metals, VOCs, SVOCs, PCBs, herbicides, and pesticides. Analytical results indicated that the combined human health and ecological COPC for AOC-1 include:

- VOCs: benzene, ethylbenzene, methylene chloride, and 1,2,4-trimethylbenzene

- SVOCs: benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, bis(2-ethylhexyl)phthalate, chrysene, indeno(1,2,3-cd)pyrene, dibenzo(a,h)anthracene, 1-methylnaphthalene, naphthalene, and pyrene

- Metals: antimony, arsenic, barium, cadmium, cobalt, hexavalent chromium, iron, lead, manganese, mercury, thallium, vanadium, and zinc.

A summary of the sources and release mechanisms associated with AOC-1 as well as the exposure pathways and receptors is provided in Figure 4.

AOC-2 Onsite Non-Operational Areas

Included in AOC-2 are areas of the refinery that were reported to not have been used for operations or storage. However, it was reported that west of Tank 31 within AOC-2 there were drums that had leaked. This was also a cooling tower sludge disposal area (Kleinfelder 2007). These areas were not assessed during the Phase I investigation and will be assessed during this investigation.

During the Phase I investigation, composite samples were collected from the surface and subsurface in AOC-2. Analytical results indicated that the COPC for AOC-2 include:

- VOCs: methylene chloride

- Metals: arsenic, cobalt, hexavalent chromium, iron, manganese, and zinc.

A summary of the sources and release mechanisms for AOC-2 as well as the exposure pathways and receptors is provided in Figure 4.

AOC-3 Wetlands

Included in AOC-3 are: (1) wetlands immediately adjacent to the site bordered by Bay Avenue, Bishop Road, and a berm on the upstream side; (2) wetlands located between Bishop Road, Sunray Road, Bay Avenue, and residences along Thayer Avenue; and (3) wetlands between Sunray Road, residences along FM 2725, Gulf Marine Fabricators, Offshore Specialty Fabricators, and the outlet of the wetlands into the Intracoastal Waterway.

There is one active and several abandoned pipelines leading from the refinery to the current and former barge dock facilities. During the Phase I investigation, wetland assessment activities evaluated releases from the refinery, including unpermitted wastewater effluent discharges, two known pipeline releases, and possible releases from pipelines leading from the refinery to the current and former barge dock facilities. Soil, sediment, and surface water were assessed for metals, VOCs, SVOCs, PCBs, herbicides, and pesticides. Analytical results indicated that the combined human health and ecological (non-differentiated by wetland freshwater and saltwater) COPC for AOC-3 include:

- VOCs: methylene chloride
- SVOCs: bis(2-ethylhexyl)phthalate
- Metals: aluminum, arsenic, barium, cobalt, copper, hexavalent chromium, iron, lead, manganese, mercury, nickel, silver, thallium, vanadium, and zinc.

Ground water was not assessed in AOC-3 during the Phase I investigation. The Superior Oil spill that occurred in 2010, after the Phase I was completed, released crude oil into the wetlands that are adjacent to AOC-1S. This area of the Superior Oil spill in AOC-3, and ground water will be assessed as part of this investigation.

A summary of the sources and release mechanisms for AOC-3 as well as the exposure pathways and receptors is provided in Figure 4.

AOC-4 Current Barge Docking Facility

Included in AOC-4 is the current barge docking facility, which is approximately 0.5 acres and is located on the Intracoastal Waterway. The fenced facility, which is connected to the refinery by pipelines, is used to load and unload barges. It was reported that only crude oil passed through the docking facility. However, refined products historically were loaded and unloaded at this docking facility. There have been no reported releases associated with this AOC. However, Phase I analytical results summarized below indicate that a release has occurred, which will require further assessment of this area.

During the Phase I, composite soil samples were collected from AOC-4 and analyzed for metals, VOCs, and SVOCs, PCBs, herbicides and pesticides. Analytical results indicated that the combined human health and ecological COPC for AOC-4 include:

- VOCs: methylene chloride
- SVOCs: benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, bis(2-ethylhexyl)phthalate, and indeno(1,2,3-cd)pyrene
- Metals: antimony, arsenic, cobalt, iron, lead, manganese, selenium, vanadium, and zinc

A summary of the sources and release mechanisms for AOC-4 as well as the exposure pathways and receptors is provided in Figure 5.

AOC-5 Intracoastal Waterway

Included in this AOC are the sediments and surface water adjacent to the current and former barge dock facility. During the Phase I Investigation sediment and surface water samples were collected and analyzed for metals, VOCs, and SVOCs, PCBs, herbicides and pesticides.

Analytical results indicated that the combined human health and ecological COPC for AOC-5 include:

- SVOCs: anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, phenanthrene, and pyrene
- Metals: arsenic, hexavalent chromium, lead, silver, thallium, and zinc

A summary of the sources and release mechanisms for AOC-5 as well as the exposure pathways and receptors is provided in Figure 5.

AOC-6 Thayer Road

Included in this AOC is the neighborhood along Thayer Road, located across Bishop Road from the refinery. During the Phase I investigation, soil and ground water were assessed within AOC-6 for VOCs, SVOCs, metals, PCBs, herbicides and pesticides. Analytical results indicated that the combined human health and ecological COPC for AOC-6 include:

- Metals: arsenic, barium, cobalt, hexavalent chromium, iron, lead, selenium, vanadium, and zinc

A summary of the sources and release mechanisms for AOC-6 as well as the exposure pathways and receptors is provided in Figure 6.

AOC-7 Bishop Road

Included in this AOC is the neighborhood along Bishop Road, located across Bishop Road from the north site. During the Phase I investigation, soil was assessed within AOC-7 for VOCs, SVOCs, metals, PCBs, herbicides and pesticides. Analytical results indicated that the combined human health and ecological COPC for AOC-7 include:

- Metals: arsenic, hexavalent chromium, iron, and lead

A summary of the sources and release mechanisms for AOC-7 as well as the exposure pathways and receptors is provided in Figure 6.

Background

During the Phase I investigation at the site, background samples were collected from soil, sediment, surface water, and ground water. The number of background samples collected was not sufficient to conduct a background analysis and eliminate COPC. Background reference areas will be based on media with similar characteristics to the media associated with the AOC being investigated. Additionally, the background reference areas shall have the same physical, chemical, geological, and biological characteristics as the site, but have not been affected by activities on the site. Also, background sample locations should not be established at locations directly influenced by, or in close proximity to, obvious sources (e.g., other sites, storm water and point source outfalls, bridges, and roadways, etc).

1.3.2.4 Determine Resources

Resources should be identified by the planning team so that constraints (e.g., budget, time, schedule) associated with collecting/evaluating data can be anticipated during the project life cycle. To assist in this evaluation, the DQO process (e.g., developing performance or acceptance criteria), the FSP (i.e., for collecting and analyzing samples), and the QAPP (i.e., for interpreting and assessing the collected data) have been completed.

EPA has tasked EA to perform the investigation and prepare the deliverables required for the site RI/FS. EA will utilize the services of the EPA's Region 6 Laboratory, the EPA Contract Laboratory Program (CLP), or a private laboratory depending on the needs of the RI/FS and the availability of the laboratory's services.

EPA will perform a review of each required deliverable and provide comments as necessary. EPA will also solicit comments from other planning team members or stakeholders as appropriate. Additional details pertaining to the schedule of events and deliverables necessary to meet this milestone are provided in the EPA-approved Work Plan and Cost Estimate (EA 2012a).

1.3.3 Step 2 – Identify the Goal of the Study

Step 2 of the DQO process involves identifying the key questions that the study attempts to address, along with alternative actions or outcomes that may result based on the answers to these key questions. These two items are combined to develop a decision statement, which is critical for defining decision performance criteria later in Step 6 of the DQO process.

The most important activities in DQO Step 2 are as follows:

- Identify principal study question(s)
- Consider alternative actions that can occur upon answering the question(s)
- Develop decision statement(s) and organize multiple decisions.

1.3.3.1 Principal Study Question

The principal study question(s) (PSQ) define the question(s) to be answered by the HHRA, ERA, and RI. The PSQs are as follows:

What are possible sources for contamination?

What are the nature and extent of soil, sediment, surface water, and ground water contamination?

What are the potential migration pathways for transport of these contaminants?

Are concentrations of site COPCs significantly greater than background?

What is the potential risk to human health and ecological receptors from exposure to site-related COPCs?

1.3.3.2 Alternative Actions

The alternative actions provide PSQ alternatives in the FS. Potential alternative actions, which will be evaluated in the FS, include, but are not limited to, the following:

- Remove or remediate the source area(s)

- Restrict access to limit exposure and fish consumption

- Mitigate migration pathways

- Address other migration/exposure pathways impacting receptors by employing engineering or institutional controls.

1.3.3.3 Decision Statement

For decision-making problems, the PSQs and alternative actions are combined to develop decision statements, which are critical for defining decision performance criteria later in DQO Step 6.

The decision statements are as follows:

Determine the location of source(s) of contamination.

Determine the nature and extent of soil, sediment, suspended sediment, surface water, and ground water contamination.

Determine the migration pathways for transport of these contaminants.

Determine whether the concentrations of site COPCs are significantly greater than background.

Determine if exposure to site-related COPCs at the site pose a potential unacceptable risk to human health and/or ecological receptors.

1.3.4 Step 3 – Identify Information Inputs

Step 3 of the DQO process determines the types and sources of information needed to resolve: (1) the decision statement or produce the desired estimates; (2) whether new data collection is necessary; (3) the information basis the planning team will need for establishing appropriate analysis approaches and performance or acceptance criteria; and (4) whether appropriate sampling and analysis methodology exists to properly measure environmental characteristics for addressing the problem.

The most important activities in DQO Step 3 are as follows:

- Identify types and sources of information needed to resolve decisions or produce estimates
- Identify the basis of information that will guide or support choices to be made in later steps of the DQO process
- Select appropriate sampling and analysis methods for generating the information.

The EPA RI/FS SOW (EPA 2012a) and EPA-approved Work Plan and Cost Estimate (EA 2012a) sets forth the framework and requirements for this effort.

1.3.4.1 Necessary Information and Sources

A variety of sources and types of information form the basis for resolving the decision statements. The following information and sources are necessary to resolve this step of the DQO process.

The decision statements are supported by the following:

Determine the location of source(s) of contamination.

- The Hazard Ranking System (HRS) Documentation Record from the Falcon Refinery and site inspections has identified several areas of former operations and spills located at the refinery and along pipelines from the refinery. Complaints by neighbors have indicated additional areas of potential concern.

- Additional soil, sediment, surface water, and ground water data will be collected in the Phase II investigation to augment the historical dataset.

Determine the nature and extent of soil, sediment, suspended sediment, surface water, and ground water contamination.

- Preliminary analytical results have identified VOCs, SVOCs, and metals at concentrations above laboratory detection limits. Next, approved laboratory sampling techniques will be employed to obtain more precise concentrations of reported COPCs in soil, sediment, surface water, and ground water during Phase II. As instructed by EPA, "concentrations will be compared to appropriate screening levels and background samples and the appropriate risk assessments, required by NCP, will be performed."

Determine the migration pathways for transport of these contaminants.

- An evaluation of the surface water transport mechanisms will be conducted to aid in understanding the transport of contamination via surface water and sediment flow in/from the intracoastal waterway and wetlands.

- An evaluation of ground water transport mechanisms will be conducted to aid in understanding the transport of contamination.

Determine whether the concentrations of site COPCs are significantly greater than background.

- Geologic and media data will be collected to evaluate the potential anthropogenic contributions of contaminants above background.

Determine if exposure to site-related COPCs pose a potential unacceptable risk to human health and/or ecological receptors.

- An ecological habitat survey may be conducted, if the previous ecological characterization performed by the PRP's contractor is not of the quality needed for this RI/FS.

- An evaluation of data, upon delineation of nature and extent, will determine if a potential unacceptable risk exists to human health and/or ecological receptors.

1.3.4.2 Basis of Information

The basis of information will guide or support choices to be made in later steps of the DQO process. The basis of information is supported by the following:

Determine the location of source(s) of contamination at the site.

- An evaluation will be performed of previous Phase I investigation data, the Phase II investigation data to be acquired, and historical documents will utilize EPA guidance documents including, but not limited to: Memorandum on Guidance for Data Usability in Risk Assessment (EPA 1992); Data Quality Assessment - Statistical Methods for Practitioners (EPA 2006c); Guidance for Data Quality Assessment (EPA 2000); and Guidance on Systematic Planning Using the Data Quality Objectives Process (EPA 2006a).

Determine the nature and extent of soil, sediment, suspended sediment, surface water, and ground water contamination at the site.

- An evaluation will be performed of previous Phase I investigation data, the acquired Phase II investigation data to be acquired, and historical documents will utilize EPA guidance documents including, but not limited to: Memorandum on Guidance for Data Usability in Risk Assessment (EPA 1992); Data Quality Assessment - Statistical Methods for Practitioners (EPA 2006c); Guidance for Data Quality Assessment (EPA 2000); and Guidance on Systematic Planning Using the Data Quality Objectives Process (EPA 2006a).

- Geologic and hydrogeologic information (e.g., soil borings, new monitoring wells, etc.) coupled with physical/chemical property data will be collected to evaluate the Falcon Refinery impacts to ground water.

Determine the migration pathways for transport of these contaminants.

- The Interim Final Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA (EPA 1988) describes the process for evaluating migration pathways. Migration pathways for the various source and COPC at the site to be investigated are identified in the preliminary CSMs (Figures 4, 5 and 6).

Determine if exposure to site-related COPCs at the site pose a potential unacceptable risk to human health and ecological receptors.

- A HHRA will be conducted in accordance with the EPA's guidance which includes, but is not limited to:

  - Risk Assessment Guidance for Superfund (RAGS), Volume I: Human Health Evaluation Manual (EPA 1989)
  - RAGS for Superfund Volume I: Human Health Evaluation Manual. Supplemental Guidance: Standard Default Exposure Factors (EPA 1991)
  - RAGS, Volume I, Human Health Evaluation Manual, Part D, Standardized Planning, Reporting, and Review of Superfund Risk Assessments (EPA 2001b)
  - Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites (EPA 2002b)
  - Regional Screening Levels for Chemical Contaminants at Superfund Sites (EPA 2012c)
  - RAGS, Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) (EPA 2004).

- An ERA will be conducted in accordance with the EPA's and TCEQ guidance which includes, but is not limited to:

  - RAGS, Volume II: Environmental Evaluation Manual (EPA 1997a); and
  - Ecological RAGS: Process for Designing and Conducting Ecological Risk Assessments (EPA 1997b, 1999).
  - State of Texas Guidance (TCEQ 2006).

1.3.4.3 Sampling and Analysis Methods

An extensive field investigation has been proposed to collect soil, sediment, surface water, and ground water data. Details pertaining to this effort are contained in the FSP (EA 2012c).

1.3.5 Step 4 – Define the Boundaries of the Study

In Step 4 of the DQO process, the target population of interest and spatial/temporal features pertinent for decision making should be identified. The most important activities in DQO Step 4 are as follows:

- Define the target population of interest

- Specify temporal or spatial boundaries and other practical constraints associated with sample/data collection.

1.3.5.1 Target Population

The site is divided into seven different AOCs as described in Section 1.3.2.3. These divisions are based on the structure (i.e., physical layout) and current use of the refinery and surrounding areas.

The sample population refers to the following media, each of which will be sampled during Phase II of the RI:

- Onsite (refinery property) soil and ground water
- Offsite soil, sediment, ground water and surface water.

1.3.5.2 Temporal and Spatial Boundaries

For Phase II of the RI, the spatial boundary includes all onsite (refinery property) and offsite AOCs. Onsite activities will focus on soil to a depth of approximately 8 ft bgs, which is the anticipated depth to ground water in the shallow aquifer based on monitor well logs from an adjacent facility.

The offsite investigation will focus on surface and subsurface soil, ground water, sediment, and surface water. After the results of this Phase II sampling are completed, a decision will be made whether to include additional offsite areas.

Data will be obtained throughout a period of approximately 2- to 3-months. Onsite and offsite investigations will be conducted simultaneously. Rainfall and flooding in the wetlands and onsite can potentially affect the temporal boundaries. The data collected under this plan will be considered representative of conditions over the period of RI, HHRA, FS, RD and RA; however, this temporal bound on data collected to date and under Phase 2 is predicated on no future spills or releases. As evidenced by the 2010 Superior Oil crude oil spill from Tank 13, if the refinery resumes operations, additional releases may affect decisions made from these data regarding nature and extent and risk to human health and the environment.

1.3.6 Step 5 – Develop the Analytical Approach

Step 5 of the DQO process involves developing an analytic approach that will guide how to analyze the study results and draw conclusions from the data. It is the intention of this step to integrate the outputs from the previous four steps with the parameters developed in this step.

The most important activities in DQO Step 5 are as follows:

- Specify the appropriate population parameters for making decisions

- Choose a workable action level and generate an “If … then … else” decision rule which involves it.

1.3.6.1 Population Parameters

The population parameter is defined as the value used in the decision statement to evaluate a decision point. The population parameter will be used as an exposure point concentration in the HHRA and ERA. A population parameter will be determined for each chemical (e.g. benzene), in each AOC (e.g., AOC 3), for each sample group (e.g., benzene in AOC 3 sediment). In this example, the population is benzene in the AOC 3 sediment. The population parameter for site comparisons will be the 95% upper confidence limit of the mean (95UCLM), which will be calculated using ProUCL version 4.00.05 (Singh, Singh, and Maichle 2010), or the maximum detected concentration, if lower.

Background statistical evaluations for soil, ground water, surface water, and sediment will also be conducted. Two-population tests will be used to determine if an exposure area is significantly greater than background. Also, background level threshold values (BTV) may be used to evaluate some datasets (e.g., property specific offsite soils).

1.3.6.2 Action Level Decision Rule

The action levels for the site will likely be either: (1) risk-based screening criteria developed during the HHRA and/or ERA, or (2) federally-mandated ground water criteria such as Maximum Contaminant Levels (MCLs).

The following risk-based screening criteria will be used to evaluate whether analytical data will be of sufficient quality for risk assessment:

Human Health Criteria

- Ground Water – The lowest screening value of MCLs (EPA 2012b) and EPA Tapwater Regional Screening Levels (RSLs) (EPA 2012c).

- Surface Water – National Recommended Water Quality Criteria (EPA 2012d). If National Recommended Water Quality Criteria do not exist, then Texas Risk Reduction Program (TRRP) Surface Water Human Health Risk-Based Exposure Limits (RBELs) (TCEQ 2012).

- Surface Soil (0 to 2 ft bgs) and Sediment (0- to 12-inches bgs) – EPA RSLs for Residential Soil (EPA 2012c). If RSLs do not exist, then TRRP Tier 1 Protective Concentration Levels (PCLs) for Residential Soil less than 0.5 acres (TCEQ 2012).

- Subsurface Soil (2 ft bgs to water table) – EPA RSLs for Protection of Groundwater (EPA 2012c). If RSLs do not exist, then TRRP PCLs for soil to ground water (TCEQ 2012).

- Aquatic life (fish samples) – Safety Levels for Fish and Fishery Products Hazards and Controls Guidance – Fourth Edition (United States Food and Drug Administration 2011).

Ecological Criteria

- Surface water – National Recommended Water Quality Criteria (EPA 2012d). If National Recommended Water Quality Criteria do not exist, then TRRP Surface Water Human Health RBELs (TCEQ 2012).

- Surface (0- to 2-ft bgs) and Subsurface Soil (2 ft bgs to water table) – EPA Ecological Soil Screening Levels (SSLs; EPA 2012e).

- Sediment (0- to 12-inches bgs) – Benthic protection based on the National Oceanic and Atmospheric Administration Screening Quick Reference Tables values (Buchman 2008).

Although it is understood that the type of residential data used to develop the EPA RSLs may differ from that which will be used in the site-specific HHRA, the residential RSLs present conservative values suitable for the initial screening.

Mineral or chemical interference may lead to elevated sample quantitation limits, which are greater than their respective risk-based screening levels. If these analytes are not detected in an area of concern and sample quantitation limits are greater than risk-based values, then they may be a source of potential risk underestimation or additional sampling may be conducted to mitigate the uncertainty. A chemical will be carried forward into the risk assessments at one-half the detection limit if a chemical's detection limit is higher than its respective screening value.

The decision rule for the site is as follows:

- If site concentrations are not significantly greater than background and are less than risk based criteria, then a risk evaluation is generally not recommended

- Else, if site concentrations are significantly greater than background or greater than risk based criteria, then a risk evaluation is generally recommended.

The primary screening levels and contract-required quantitation limits (CRQLs) are provided in Appendix A. Screening levels and CRQLs for ground water, surface water, soil (surface and subsurface), and sediment are presented in tables A-1, A-2, A-3, and A-4, respectively.

EPA's new Integrated Risk Information System (IRIS) is a human health assessment program that evaluates information on health effects that may result from exposure to environmental contaminants. IRIS values are being proposed for PCBs and are expected to be finalized in June 2013. Once published, these values will be considered during evaluation of the Phase II investigation results.

The EPA recommends that a toxicity equivalence factor (TEF) methodology be used to evaluate human health risks posed by PCBs using 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) as the index chemical (EPA 2010a). The TEFs provided in "Recommended Toxicity Equivalence Factors (TEFs) for Human Health Risk Assessments of 2,3,7,8-Tetrachlorodibenzo-p-dioxin and Dioxin-Like Compounds" will be used to evaluate the health risks posed by PCB-contamination identified during the Phase II investigation.

Fish tissue samples will be collected during the Phase II investigation and analyzed for lipids, metals, SVOCs, PCBs, and pesticides. The primary screening levels and CRQLs for these analyses are presented in table A-5 in Appendix A.

1.3.7 Step 6 – Specify the Performance or Acceptance Criteria

Step 6 of the DQO process specifies the tolerable limits on decision errors. Data are subject to various types of errors (e.g., how samples were collected, how measurements were made, etc.).

As a result, estimates or conclusions that are made from the collected data may deviate from what is actually true within the population. Therefore, there is a chance that an erroneous conclusion could be made or that the uncertainty in the estimates will exceed what is acceptable.

The performance or acceptance criteria for collected data will be derived to minimize the possibility of either making erroneous conclusions or failing to keep uncertainty in estimates to within acceptable levels. Performance criteria and QA practices will guide the design of new data collection efforts. Acceptance criteria will guide the design of procedures to acquire and evaluate existing data.

The most important activities in DQO Step 6 are as follows:

- Recognizing the total study error and devising mitigation techniques to limit error.
- Specify the decision rule as a statistical hypothesis test, examine consequences of making incorrect decisions from the test, and place acceptable limits on the likelihood of making decision errors.

1.3.7.1 Total Study Error

Even though unbiased data collection methods may be used, the resulting data will still be subject to random and systematic errors at different stages of the collection process (e.g., from field sample collection to sample analysis). The combination of these errors is called the "total study error" (or "total variability") associated with the collected data. There can be many contributors to total study error, but there are typically two main components, sampling error and measurement error.

Sampling Error

Sampling error, sometimes called statistical sampling error, is influenced by the inherent variability of the population over space and time, the sample collection design, and the number of samples collected. It is usually impractical to measure the entire population space, and limited sampling may miss some features of the natural variation of the measurement of interest. Sampling design error occurs when the data collection design does not capture the complete variability within the population space, to the extent appropriate for making conclusions. Sampling error can lead to random error (i.e., random variability or imprecision) and systematic error (bias) in estimates of population parameters. In general, sampling error is much larger than measurement error and consequently needs a larger proportion of resources to control.

Measurement Error

Sometimes called physical sampling error, measurement error is influenced by imperfections in the measurement and analysis protocols. Random and systematic measurement errors are introduced in the measurement process during physical sample collection, sample handling, sample preparation, sample analysis, data reduction, transmission, and storage.

The potential for measurement error will be mitigated by using accurate measurement techniques. Sampling techniques were selected to limit the measurement error, including the following:

- Sample collection procedures, sample processing, and field sample analysis protocols are standardized and documented in standard operating procedures (SOPs) to ensure that the methodology remains consistent and limits the potential for measurement error.

- Field teams will be trained and will perform specific tasks (e.g., sample collection or processing) throughout the field sampling effort to limit the potential for measurement error.

- Potential for measurement error in the sample analysis will be limited by the analysis of QC samples (e.g., duplicates).

1.3.7.2 Statistical Hypothesis Testing and Decision Errors

Decision-making problems are often transformed into one or more statistical hypothesis tests that are applied to the collected data. Data analysts make assumptions on the underlying distribution of the parameters addressed by these hypothesis tests, in order to identify appropriate statistical procedures for performing the chosen statistical tests.

Due to the inherent uncertainty associated with the collected data, the results of statistical hypothesis tests cannot establish with certainty whether a given situation is true. There will be some likelihood that the outcome of the test will lead to an erroneous conclusion (i.e., a decision error).

When a decision needs to be made, there are typically two possible outcomes: either a given situation is true, or it is not. Although it is impossible to know whether an outcome is really true, data are collected and statistical hypothesis testing is performed to make an informed decision. In formulating the statistical hypothesis test, one of the two outcomes is labeled the “baseline condition” and is assumed to represent the *de facto*, true condition going into the test, and the other situation is labeled the “alternative condition.” The baseline condition is retained until the information (data) from the sample indicates that it is highly unlikely to be true.

The statistical theory behind hypothesis testing allows for defining the probability of making decision errors. However, by specifying the hypothesis testing procedures during the design phase of the project, the performance or acceptance criteria can be specified.

There are four possible outcomes of a statistical hypothesis test. Two of the four outcomes may lead to no decision error; there is no decision error when the results of the test lead to correctly adopting the true condition, whether it is the baseline or the alternative condition. The remaining two outcomes represent the two possible decision errors. The first is a false rejection decision error, which occurs when the data leads to decision that the baseline condition is false when, in reality, it is true. The second is a false acceptance decision error, which occurs when the data are insufficient to change the belief that the baseline condition is true when, in reality, it is false.

In the statistical language of hypothesis testing, the baseline condition is called the "null hypothesis" (H_o) and the alternative condition is called the "alternative hypothesis" (H_a). A false rejection decision error, or a Type I error, occurs when you reject the null hypothesis when it is actually true. The probability of this error occurring is called alpha (α) and is called the hypothesis test's level of significance. A false acceptance decision error, or a Type II error, occurs when you fail to reject the null hypothesis when it is actually false. The probability that this error will occur is called beta (β). Frequently, a false rejection decision error is the more severe decision error, and therefore, criteria placed on an acceptable value of alpha (α) are typically more stringent than for beta (β). Statisticians call the probability of rejecting the null hypothesis when it is actually false the statistical power of the hypothesis test. Statistical power is a measure of how likely the collected data will allow you to make the correct conclusion that the alternative condition is true rather than the default baseline condition and is a key concept in determining DQOs for decision-making problems. Note that statistical power represents the probability of "true rejection" (i.e., the opposite of false acceptance) and, therefore, is equal to $1-\beta$.

Decision errors can never be totally eliminated when performing a statistical hypothesis test. However, the primary aim of this step is to arrive at the upper limits on the probabilities of each of these two types of decision errors that the planning team finds acceptable.

Background Evaluation

COPCs in soil, sediment, surface water, and ground water will be subject to a background evaluation to determine whether site concentrations are significantly greater than background. Two-population tests will be used to determine if an exposure area is significantly greater than background. Because the site may be impacted, the null hypothesis is the mean concentration of a contaminant does not exceed (i.e., is not greater than or equal to) the mean background concentration and the alternative hypothesis is the mean concentration does exceed the mean background concentration as follows:

H_o = Mean Media Analyte Concentration ≤ Mean Media Analyte Background

H_a = Mean Media Analyte Concentration > Mean Media Analyte Background

Also, background threshold values may be used to evaluate some datasets. The null hypothesis is the mean concentration of a contaminant does not exceed (i.e., is not greater than or equal to) the action level or background dataset and the alternative hypothesis is the mean concentration does exceed the action level as follows:

H_o = Mean Media Analyte Concentration ≤ Action Level

H_a = Mean Media Analyte Concentration > Action Level

For the statistical evaluations conducted for the site, the probability of a Type I error occurring will be established at 5 percent and a Type II error will be established at 10 percent.

1.3.8 Step 7 – Develop the Plan for Obtaining Data

In the Steps 1 through 6 of the DQO process, performance or acceptance criteria were developed. The goal of Step 7 is to develop a resource-effective sampling design for collecting and measuring environmental samples, or for generating other types of information needed to address the PSQ. In addition, this sampling design will lead to data that will achieve the performance and acceptance criteria.

The most important activity in DQO Step 7 is as follows:

- Use the information from Steps 1 through 6 of the DQO process to identify a sampling and analysis design that will answer the PSQ and achieve the performance or acceptance criteria.

Visual Sample Plan

VSP Version 6.3 was utilized to determine an appropriate amount of surface soil, subsurface soil, sediment, surface water, and ground water samples needed to achieve site investigation goals, and to determine sample locations for AOC 1 and AOC 3. The VSP reports generated for AOC 1 and 3 are presented in Appendix B. The first page of Appendix B lists all the reports generated through VSP. In essence, VSP was used to calculate the minimum number of samples and sample locations per media, per AOC, and per risk assessment type (i.e. human health and ecological).

For AOC 1, surface and subsurface soil concentrations were compared to human health and ecological benchmarks while groundwater was compared to human health benchmarks. For AOC 3, which encompasses a few wetland areas, surface soil, subsurface soil, surface water, and sediment were compared to human health and ecological benchmarks.

Because the sampling goal is to compare average AOC concentrations to a benchmark, it was determined that comparing the site population against a fixed value (e.g., human health screening values or ecological screening values) was the appropriate VSP module to use to determine minimum sample size.

VSP was used to compute the minimum sample size using a one-sample *t*-test to discern a difference ("gray region" or delta) of either the absolute value of the difference between the sample mean and the benchmark or one half the sample standard deviation, whichever is greatest, between the mean analyte concentration and its screening level value.

Delta = |*sample mean - benchmark*| **OR** *0.5 × sample standard deviation*, **whichever is greatest**

This "gray region" is the concentration range in which site decisions cannot be made at the specified Type I or Type II error rates. The smaller the tolerable gray region, the greater the numbers of samples that are required. A gray region of less than half a standard deviation is more difficult to resolve unless a larger number of measurements are available and relative differences of more than three standard deviations are easier to resolve, but may lack statistical robustness. Therefore, the use of the greatest value between the two specified deltas for the gray region was considered appropriate.

Screening Level Evaluation

The null hypothesis is that the mean concentration exceeds the screening level (i.e., sample is impacted) and the alternative hypothesis is that the mean concentration of a contaminant does not exceed the screening level as follows:

Ho = Mean Media Analyte Concentration ≥ Screening Level

Ha = Mean Media Analyte Concentration ≤ Screening Level

For the statistical evaluations conducted for the site, the probability of a Type I error occurring was established at 5 percent and a Type II error was established at 10 percent.

A systematic grid, random start, sampling approach was used to establish the minimum quantity of samples and randomized sample locations. Appendix C summarizes the quantity of samples VSP calculated for each analyte, media, AOC, and screening level. Once the minimum amount of samples required was calculated, the amount of Phase I samples was compared to the minimum amount of samples calculated. If the amount of Phase I samples was greater than the minimum amount of samples calculated, zero amount of samples were recommended to be collected. If the amount of Phase I samples was less than the minimum amount of samples, then the amount of Phase I samples was subtracted from the minimum amount of samples calculated and that value was used as the proposed quantity of samples needed to achieve site goals. The analyte data used for the calculations in this QAPP is the same data that was used in the previous FSP (Kleinfelder 2009b) for VSP calculations. For each AOC/Media/Benchmark, the analyte with the greatest quantity of proposed samples was used as the driving analyte. Table C-0, within Appendix C, summarizes the proposed number of additional samples for each AOC and media type.

Sample Quantities

VSP determined that 16 additional groundwater samples in AOC 1, 25 additional soil samples (surface and subsurface) in AOC 3, and 29 additional surface water samples in AOC 3 were necessary to test the null hypothesis. The soil samples and surface water samples for AOC 3 will be proposed for collection. However, only 15 groundwater sample locations will be proposed and the location of the monitoring wells will be selected by EA using best professional judgment, instead of using the VSP locations. In addition, judgmental samples will be collected from AOC 1, 2, 3, 4, 6, and 7. The sample locations for AOC 2, 4, and 5, determined in the previous FSP (TRC 2011) written for the site, were deemed appropriate for use in this QAPP by EA and will be used in addition to the samples EA is already proposing. Upon review of historical data, EA has also decided to collect judgmental samples in AOC 6 and 7. Please see Table C-0, within Appendix C, for a summary of sample quantities being proposed and see the Figures section of the FSP (EA 2012c) for maps showing the placement of samples and monitor wells.

Sampling Strategy Summary

The sampling strategy for the site is detailed in the FSP (EA 2012c).

1.4 QUALITY ASSURANCE OBJECTIVES FOR MEASUREMENT DATA

A well-defined QA/QC process is integral to the generation of analytical data of known and documented quality. The QC process includes those activities required during data collection to produce data of sufficient quality to support the decisions that will be made based on the data (e.g., decisions to be made prior to, during, and after site remedial actions) (EPA 2006a). After environmental data are collected, QA activities focus on evaluating the quality of the data to determine the usability of data to support for remedial or enforcement decisions. Table 3 presents the acceptance criteria for definitive onsite and offsite laboratory data for chemical analyses of investigation samples only.

1.4.1 Data Categories

In order to produce data suitable for decision-making, an appropriate analytical technique must be selected. The EPA Superfund program has developed two descriptive categories of analytical techniques: (1) field-based techniques; and (2) fixed-laboratory techniques. The type of data generated depends on the qualitative and quantitative DQOs developed for a project. Regardless of whether the data was analyzed utilizing field or laboratory techniques, it must be of adequate quality for the decision-making process for which it was collected. For this project, data from both types of techniques will be collected. Section 2 discusses the methods that will be used to analyze the samples. Both field-based and definitive analytical data will be used to support decisions made for this project.

Rigorous analytical methods (e.g., EPA CLP methods) are used to generate analyte-specific, definitive data. The definitive quality of the data is assured by: (1) using SOPs and QC processes during data collection; (2) documented control and traceability of reference standards, calibrations, and instrument performance; and (3) acceptable performance of field and laboratory QC procedures within the defined limits established for these procedures.

TABLE 3 QUALITY ASSURANCE INDICATOR CRITERIA

Indicator Parameter	Analytical Parameter	QC Sample	Acceptance Criteria for Laboratory Analysis
Accuracy (percent recovery)	VOCs, SVOCs, pesticides, herbicides, PCB Aroclors and congeners	MS, MSD Blanks	50 to 150 percent recovery Less than CRQL
	TAL metals and TSS	MS LCS Blanks [a]	75 to 125 percent recovery 80 to 120 percent recovery Less than CRDL
Precision (RPD)	VOCs, SVOCs, pesticides, herbicides, PCB Aroclors and congeners	MS, MSD Field duplicates	30 percent RPD 50 percent RPD
	TAL Metals and TSS	MS, MSD or MD Field duplicates	20 percent RPD (aqueous) 35 percent RPD (solid) 50 percent RPD

Indicator Parameter	Analytical Parameter	QC Sample	Acceptance Criteria for Laboratory Analysis
Sensitivity (quantitation limits)	Analytical tests	MS, MD, MSD Field duplicates	Not applicable
Completeness	The objective for data completeness is 90 percent.		
Representativeness	The sampling network and analytical methods for this site are designed to provide data that are representative of site conditions.		
Comparability	The use of standard published sampling and analytical methods, and the use of QC samples, will ensure data of known quality. These data can be compared to other data of known quality.		

NOTE:

[a] May include method blanks, reagent blanks, instrument blanks, calibration blanks, and other blanks collected in the field (such as field blanks)

CRDL = Contract-required detection limit
CRQL = Contract-required quantitation limit
LCS = Laboratory control sample
MD = Matrix duplicate
MDL = Method detection limit
MS = Matrix spike
MSD = Matrix spike duplicate
QC = Quality control
RPD = Relative percent difference
SVOC = Semi-volatile organic compound
TAL = Target Analyte List
VOC = Volatile organic compound

Based on technical direction provided by EPA, fixed-laboratory analysis for samples collected during the RI/FS sampling event will be conducted by the EPA Region 6 Laboratory, an EPA-designated CLP laboratory, or a subcontracted non-CLP laboratory

1.4.2 Measurement Quality Objectives

The analytical results will be evaluated in accordance with precision, accuracy, representativeness, completeness, and comparability (PARCC) parameters to document the quality of the data and to ensure that the data are of sufficient quality to meet the project objectives. Of these PARCC parameters, precision and accuracy will be evaluated quantitatively by review of the results of QC check samples listed in Table 3.

The sections below describe each of the PARCC parameters and how they will be assessed within this project.

1.4.2.1 Precision

Precision is the degree of mutual agreement between individual measurements of the same property under similar conditions. Usually, combined field and laboratory precision is evaluated by collecting and analyzing field duplicates and then calculating the variance between the samples, typically as a relative percent difference (RPD).

RPD is calculated as follows:

$$\mathrm{RPD} = \frac{|\mathrm{A} - \mathrm{B}|}{(\mathrm{A} + \mathrm{B})/2} \times 100\%$$

where: A = Original sample concentration
B = Duplicate concentration

Field sampling precision is evaluated by analyzing field duplicate samples. For every 10 samples collected, one soil duplicate sample will be collected to yield a minimum field duplicate frequency of 10 percent.

Laboratory analytical precision is evaluated by analyzing laboratory duplicates (also called matrix duplicates [MDs]) or matrix spikes (MSs) and matrix spike duplicates (MSDs). For this project, MS/MSD and original sample (OS)/MD samples will be generated for analytes. The results of the analysis of each MS/MSD or OS/MD pair will be used to calculate the RPD as a measure of lab precision. In addition, laboratory control samples (LCSs) and LCS duplicates are also used for laboratory precision. The RPD acceptance criteria are listed in Table 3.

1.4.2.2 Accuracy

A program of sample spiking will be conducted to evaluate laboratory accuracy. This program includes analysis of the MS and MSD samples, LCSs or blank spikes, surrogate standards, and method blanks. MS and MSD samples will be prepared and analyzed at a frequency of 5 percent for soil samples. LCSs or blank spikes are also analyzed at a frequency of 5 percent. Surrogate standards, where available, are added to every sample analyzed for organic constituents. The results of the spiked samples are used to calculate the percent recovery for evaluating accuracy.

$$\text{Percent Recovery} = \frac{\mathrm{S} - \mathrm{C}}{\mathrm{T}} \times 100\%$$

where: S = measured spike sample concentration
C = sample concentration
T = true or actual concentration of the spike

The objective for accuracy of field measurements is to achieve and maintain factory specifications for the field equipment.

1.4.2.3 Representativeness

Representativeness expresses the degree to which sample data accurately and precisely represent the characteristics of a population, variations in a parameter at a sampling point, or an environmental condition that they are intended to represent. For this project, representative data will be obtained through careful selection of sampling locations and analytical parameters. Representative data will also be obtained through proper collection and handling of samples to avoid interference and minimize contamination.

Representativeness of data will also be ensured through the consistent application of established field and laboratory procedures. Field blanks (if appropriate) and laboratory blank samples will be evaluated for the presence of contaminants to aid in evaluating the representativeness of sample results. Data determined to be non-representative, by comparison with existing data, will be used only if accompanied by appropriate qualifiers and limits of uncertainty.

1.4.2.4 Completeness

Completeness is a measure of the percentage of project-specific data that are valid. Valid data are obtained when samples are collected and analyzed in accordance with QC procedures outlined in this QAPP, and when none of the QC criteria that affect data usability are exceeded. When data validation is completed, the percent completeness value will be calculated by dividing the number of useable sample results by the total number of sample results planned for this investigation.

Completeness will also be evaluated as part of the data quality assessment process (EPA 2006c; 2006d). This evaluation will help determine whether limitations are associated with the decisions to be made based on the data collected.

1.4.2.5 Comparability

Comparability expresses the confidence with which one data set can be compared with another. Comparability of data will be achieved by consistently following standard field and laboratory procedures and by using standard measurement units in reporting analytical data. Standard EPA analytical methods and QC will be used to support the comparability of analytical results with those obtained in other testing. Calibrations will be performed in accordance with EPA or manufacturer's specifications and will be checked with the frequency specified in the EPA CLP SOW(s) or applicable method.

1.4.3 Detection and Quantitation Limits

The analytical parameters and their quantitation limits for use on this project are determined under the EPA CLP SOW(s) or applicable method. The contract-required detection limit (CRDL) is the minimum concentration of an analyte that can be reliably distinguished from background noise for a specific analytical method. The quantitation limit represents the lowest concentration of an analyte that can be accurately and reproducibly quantified in a sample matrix. CRQLs are contractually specified maximum quantitation limits for specific analytical methods and sample matrices, such as soil or water, and are typically several times the method detection limit (MDL) to allow for matrix effects.

For this project, analytical methods have been selected so that the CRQL for each target analyte is below the applicable regulatory screening criteria, wherever practical. For this project, samples results will be reported as estimated values if concentrations are less than CRQLs but greater than CRDLs. The CRDL for each analyte will be listed as the detection limit in the laboratory's electronic data deliverable (EDD). All data with estimated qualifiers will be assumed to be positive identifications for the chemical in that medium and the corresponding reported concentrations will be used.

1.5 SPECIAL TRAINING AND CERTIFICATION

This section outlines the training and certification required to complete the activities described in this QAPP. The following sections describe the requirements for the EA team and subcontractor personnel working onsite.

1.5.1 Health and Safety Training

EA field team personnel who work at hazardous waste project sites are required to meet the Occupational Safety and Health Administration (OSHA) training requirements defined in 29 Code of Federal Regulations (CFR) 1910.120(e). These requirements include: (1) 40 hours of formal offsite instruction; (2) a minimum of 3 days of actual onsite field experience under the supervision of a trained and experienced field supervisor; and (3) 8 hours of annual refresher training. Field personnel who directly supervise employees engaged in hazardous waste operations also receive at least 8 additional hours of specialized supervisor training.

Copies of the field team's health and safety training records, including course completion certifications for the initial and refresher health and safety training, and specialized supervisor training are maintained in project files.

For more health and safety details, see EA's site-specific Health and Safety Plan (EA 2012d).

1.5.2 Subcontractor Training

Subcontractors who work onsite will certify that their employees have been trained for work on hazardous waste project sites. Training will meet OSHA requirements defined in 29 CFR 1910.120(e). Before work begins at the project site, subcontractors will submit copies of the training certification for each employee to EA.

Employees of associate and professional services firms and technical services subcontractors will attend a safety briefing and complete the Safety Meeting Sign-Off Sheet before they conduct onsite work (EA 2012d). This briefing is conducted by the EA Site Health and Safety Officer or other qualified person.

Subcontractors are responsible for conducting their own safety briefings; EA personnel may audit these briefings. Alternatively, the subcontractors may elect to attend the EA safety briefings.

1.6 DOCUMENTS AND RECORDS

The following sections discuss the requirements for documenting field activities and for preparing laboratory data packages. This section also describes reports that will be generated as a result of this project.

1.6.1 Field Documentation

Field personnel will use permanently bound field logbooks with sequentially numbered pages to record and document field activities and will follow SOP 016 for completing field logbooks (EA 2012c). The logbook will list the contract name and number; site name; and names of subcontractors, service client, and Project Manager. At a minimum, the following information will be recorded in the field logbook:

- Name and affiliation of onsite personnel or visitors
- Weather conditions during the field activity
- Summary of daily activities and significant events
- Notes of conversations with coordinating officials
- References to other field logbooks or forms that contain specific information
- Discussions of problems encountered and their resolution
- Discussions of deviations from the QAPP, FSP, or other governing documents
- Description of photographs taken.

1.6.2 Laboratory Documentation

This section describes the data reporting requirements for EA field personnel and laboratories (e.g., EPA CLP laboratories, EPA Region 6 laboratory, or subcontracted non-CLP laboratories) that submit field and laboratory measurement data under the EPA Region 6 RAC II Program.

EA will require fixed offsite non-CLP laboratories to prepare and submit data packages in accordance with the EPA CLP protocols (2007, 2008, 2010a,b,c, 2011) for hardcopy and EDD format of data. Data packages will include applicable documentation for independent validation of data and verification of the DQOs. The following documentation will be required for full data validation:

- Case narratives, which will describe QC non-conformances that are encountered during the receipt, storage, preparation, analysis, and reporting of samples in addition to corrective actions that are taken:

  — Statement of samples received
  — Description of deviations from the specified analytical method
  — Explanations of data qualifiers that are applied to the data
  — Other significant problems that were encountered.

- Tables that cross-reference field and laboratory sample numbers;

- Chain-of-custody forms, which pertain to each sample delivery group or sample batch that is analyzed

- Laboratory reports, which must show traceability to the sample analyzed and must contain specified information:

  — Project identification

- Field sample number
- Laboratory sample number
- Sample matrix description
- Dates and times of sample collection, receipt at the laboratory, preparation, and analysis
- Description of analytical method and reference citation
- Results of individual parameters, with concentration units, including second column results, second detector results, and other confirmatory results, where appropriate
- Quantitation limits achieved
- Dilution or concentration factors.

• Data summary forms and QC summary forms showing analytical results, if applicable:

- Samples
- Surrogates
- Blanks
- Field QC samples
- LCS
- Initial and continuing calibrations
- Other QC samples.

• Laboratory control charts:

- Raw data
- Instrument printouts
- Laboratory bench sheets for preparation of samples.

• MDL study results.

EA's Project Manager, in cooperation with the QA Officer, will define site-specific requirements for data reporting. Requests for analytical services define these requirements, the turnaround time for receipt of the data deliverables specified, and requirements for retaining samples and laboratory records. Laboratory QA managers are responsible for ensuring that laboratory data reporting requirements in this QAPP are met.

1.6.3 Full Data Package

When a full data package is required, the laboratory will prepare data packages in accordance with the instructions provided in the EPA CLP SOWs (EPA 2007, 2008, 2010a,b,c, 2011). Full data packages will contain the information from the summary data package and associated raw data. Full data packages are due to EA within 35 days after the last sample in the sample delivery group is received. Unless otherwise requested, the subcontractor will deliver one copy of the full data package.

1.6.4 Reports Generated

Following the completion of the RI field program and receipt of validated data, EA will prepare the following reports:

- DESR
- Baseline HHRA Report
- ERA Report
- RI Report
- ADSM
- RACA Report
- FS Report.

The specific requirements and elements of each of these reports are discussed in detail in the EPA-approved Work Plan and Cost Estimate (EA 2012a).

2. DATA GENERATION AND ACQUISITION

This section describes the requirements for the following items:

- Sampling process design (Section 2.1)
- Sampling methodology (Section 2.2)
- Decontamination (Section 2.3)
- Management of IDW (Section 2.4)
- Sample container, volume, preservation, and holding time requirements (Section 2.5)
- Sample handling and custody (Section 2.6)
- Analytical methods requirements (Section 2.7)
- QC requirements (Section 2.8)
- Instrument calibration and frequency (Section 2.9)
- Requirements for inspection and acceptance of supplies and consumables (Section 2.10)
- Data acquisition requirements (Section 2.11)
- Data management (Section 2.12).

2.1 SAMPLING PROCESS DESIGN

For the activities associated with this Task Order and QAPP, the main elements of the sampling design include the numbers and types of samples to be collected, sampling locations, sampling frequencies, and sample matrices.

As stated in the DQOs (Section 1.3), the following principal study questions were formulated for the RI:

What are possible sources for contamination?

What are the nature and extent of soil, sediment, suspended sediment, surface water, and ground water contamination?

What are the potential migration pathways for transport of these contaminants?

Are concentrations of site COPCs significantly greater than background?

What is the potential risk to human health and ecological receptors from exposure to site-related COPCs?

The primary objective of the sampling design is to collect data of sufficient quantity and quality to resolve the study question and support risk assessment and remedy evaluation. The purpose of the RI/FS is to determine the nature and extent of contamination and to gather sufficient information so that the EPA can select a remedy that eliminates, reduces, or controls risks to human health or the environment, as follows:

Determine the location of source(s) of contamination.

Determine the nature and extent of soil, sediment, suspended sediment, surface water, and ground water contamination.

Determine the migration pathways for transport of these contaminants.

Determine whether the concentrations of site COPCs are significantly greater than background.

Determine if exposure to site-related COPCs at the site pose a potential unacceptable risk to human health and/or ecological receptors.

The goal is to develop the minimum amount of data necessary to support the selection of an approach for the site's investigation, and then to use the data to support a ROD. To achieve this goal, soil, sediment, suspended sediment, surface water, and ground water will be sampled during the RI/FS at the site.

The TRC Field Sampling Plan Addendum No. 1a (TRC 2011) summarizes the historical soil data that are available and its suitability for use to either: (1) qualitatively evaluate the nature and extent of contamination; or (2) definitively evaluate potential risk to human health and ecological receptors. Discussion of sampling rationale and locations to be sampled is included in the site-specific FSP (EA 2012c).

2.2 SAMPLING METHODOLOGY

Samples will be collected per the methods described in the site-specific FSP (EA 2012c) in accordance with EA SOPs. During sample collection, preparation, and field analysis, chain-of-custody will be maintained and documented.

Samples for fixed laboratory analysis will be processed and handled in accordance with the CLP

Guidance for Field Samplers (EPA 2011) and/or SOP 004 (EA 2012c), as applicable.

2.3 DECONTAMINATION

Re-usable field equipment utilized during the RI/FS will be decontaminated prior to and after use (SOP 005 in EA 2012c). Decontamination of field equipment will occur in buckets, plastic containers, or other similar containers with sealing lids, and the resulting fluid will be transferred to 55-gallon investigation-derived waste (IDW) drums staged in a designated staging area (Support Zone). The decontamination water will be properly sampled and disposed of following local, State, and Federal guidelines.

2.4 MANAGEMENT OF INVESTIGATION-DERIVED WASTE

Best management practices of green remediation will be incorporated as it relates to the management of IDW. Drill cuttings from the site will be containerized prior to characterization and offsite disposal. IDW soil samples will be submitted to an EA-subcontracted laboratory for disposal characterization. Landfill Disposal Restrictions will dictate sample quantities and analysis.

Decontamination water generated during well installation, ground water sampling, and equipment decontamination will be drummed, sealed, labeled, and stored at the designated staging area (Support Zone) until profiled for acceptance at an approved disposal facility (SOP 042 in EA 2012c). IDW water samples will be submitted to an EA-subcontracted laboratory for disposal characterization.

2.5 SAMPLE CONTAINER, VOLUME, PRESERVATION, AND HOLDING TIME REQUIREMENTS

Table 4 specifies the required sample volume, container type, preservation technique, and holding time for each analysis that is to be conducted during each phase of sampling. Required containers, preservation techniques, and holding times for field QC samples, such as field duplicates, will be the same as for investigative samples, but may require additional volumes.

2.6 SAMPLE HANDLING AND CUSTODY

Each sample collected by the EA field team will be traceable from the point of collection through analysis and final disposition to ensure sample integrity. Sample integrity helps to ensure the legal defensibility of the analytical data and subsequent conclusions. Sample handling will follow CLP protocols as required in EPA's CLP Guidance for Field Samplers (EPA 2011).

The EA field team will use EPA's data management system known as SCRIBE to generate chain-of-custody records in the field. Applicable copies of generated SCRIBE files will be delivered to EPA data management personnel as required by CLP protocols.

2.7 ANALYTICAL METHODS REQUIREMENTS

The source of analytical services to be provided will be determined in part by DQOs and the intended use of the resulting data. EA will use EPA-approved methods for laboratory analyses of the samples.

EA will follow the analytical services requested procedures that are outlined the Analytical Services Delivery Plan (EA 2005). If an analytical system fails, the QA Officer will be notified, and corrective action will be taken. In general, corrective actions will include stopping the analysis, examining instrument performance and sample preparation information, and determining the need to re-prepare and reanalyze the samples.

Laboratories that are subcontracted by EA or EPA will conduct definitive laboratory analysis of samples. Table 4 lists the laboratory analytical methods for this project. In cases, appropriate methods of sample preparation, cleanup, and analyses are based on specific analytical parameters of interest, sample matrices, and required quantitation limits. The following sections briefly discuss each analytical method and required modifications for definitive investigative analyses. Analyses for the IDW profiling will be conducted according to the specifications in the selected analytical method listed in Table 4.

TABLE 4 REQUIRED VOLUME, CONTAINERS, PRESERVATIVES, AND HOLDING TIMES

Parameter	Method	Volume and Container	Preservatives	Holding Time [a]
Investigative Solid Samples				
Metals (including mercury)	CLP ISM01.3	One 8-ounce amber glass jar with Teflon™-lined cap	Store at 4±2°C	180 days (28 days for mercury)
VOCs	CLP SOM01.2	Three 5-gram EnCore samplers and One 4-ounce glass jar with Teflon™-lined cap	Store at 4±2°C	48 hours
SVOCs	CLP SOM01.2	One 8-ounce amber glass jar with Teflon™-lined cap	Store at 4±2°C	14 days
Pesticides	CLP SOM01.2	One 8-ounce amber glass jar with Teflon™-lined cap	Store at 4±2°C	14 days
PCBs as Aroclors	CLP SOM01.2	One 8-ounce amber glass jar with Teflon™-lined cap	Store at 4±2°C	14 days
Herbicides	SW-846 8151	One 8-ounce amber glass jar with Teflon™-lined cap	Store at 4±2°C	14 days
PCB Congeners	EPA 1668B	One 8-ounce amber glass jar with Teflon™-lined cap	Store at 4±2°C	360 days
TOC	Walkley Black	One 8-ounce amber glass jar with Teflon™-lined cap	Store at 4±2°C	28 days
Particle Size	ASTM D422	500 grams of material in sealed plastic bag	None	None
Lipids	--	Amber glass jar with Teflon™-lined cap	Store at 4±2°C	1 year
Investigative Water Samples				
Metals (including mercury)	CLP ISM01.3	One 1-liter HDPE bottle	Nitric acid to pH ≤ 2; Store at 4±2°C	180 days (28 days for mercury)
VOCs	CLP SOM01.2	Three 40-milliliter amber volatile organic analyte (VOA) glass vials with Teflon™-lined cap	Hydrochloric acid to pH≤2; Store at 4±2°C	14 days
SVOCs	CLP SOM01.2	Two 1-liter amber glass bottles	Store at 4±2°C	7 days
Pesticides	CLP SOM01.2	Two 1-liter amber glass bottles	Store at 4±2°C	7 days
PCB Aroclors	CLP SOM01.2	Two 1-liter amber glass bottles	Store at 4±2°C	7 days
PCB Congeners	EPA 1668B	One 1-liter amber glass bottle	Store at 4±2°C	360 days
TSS	SM 2540 D	One 1-liter HDPE bottle	Store at 4±2°C	7 days
Investigative Soil Vapor Samples				
VOCs	TO 15	6-liter Summa canister	---	28 days
IDW Special Analysis				
Reactivity Corrosivity Ignitability	SW-846 Method 9045C or 9040B, Method 1030, and Chapter 7	One 8-ounce amber glass jar with Teflon™-lined cap	Store at ≤6°C	NA/72 hours
TCLP metals	SW-846	One 8-ounce amber glass jar with	Store at ≤6°C	180 days

Parameter	Method	Volume and Container	Preservatives	Holding Time [a]
(including mercury)	Methods1311/6010B /7470A	Teflon™-lined cap		except mercury is 28 days

NOTE:

a Holding time is measured from the time of sample collection to the time of sample extraction and/or analysis.
CLP = Contract Laboratory Program
HDPE = high-density polyethylene
PCB = Polychlorinated biphenyl
SVOC = Semi-volatile organic compound
TAL = Target Analyte List
TCLP = Toxicity Characteristic Leaching Procedure
VOC = Volatile organic compound

The source of analytical services to be provided will be determined in part by DQOs and the intended use of the resulting data. EA will use EPA-approved methods for laboratory analyses of the samples.

2.7.1 Field Analytical Methods

Water quality parameters that include pH, temperature, specific conductivity, oxidation-reduction potential, dissolved oxygen, and turbidity will be monitored using field-based methods during the collection of ground water samples. Water quality parameters that include pH, temperature, specific conductivity, oxidation-reduction potential, total dissolved solids (TDSs), and turbidity will be monitored using field-based methods during the collection of surface water samples. EA will follow manufacturer-recommended procedures for operating field equipment.

2.7.2 Fixed-Laboratory Analytical Methods

Fixed-laboratory analyses will be conducted by EPA Region 6, a designated CLP laboratory, or a subcontracted non-CLP laboratory. Samples submitted to the analytical laboratory will be analyzed in accordance with CLP SOWs SOM01.2 (EPA 2007; 2008) and ISM01.3 (EPA 2010b,c,d). Modifications to analytical methods that may be required to manage atypical matrices or to achieve low quantitation limits are not anticipated. Decisions regarding the use and type of method modifications will be made during the procurement of laboratories, as different laboratories have equipment and SOPs that generate varying quantitation limits.

2.8 QUALITY CONTROL REQUIREMENTS

Various field and laboratory QC samples and measurements will be used to verify that analytical data meet the QA objectives. Field QC samples and measurements will be collected to assess the influence of sampling activities and measurements on data quality. Similarly, laboratory QC samples will be used to assess how the laboratory's analytical program influences data quality. This section describes the QC samples that are to be analyzed during the site sampling activities for: (1) each field and laboratory environmental measurement method; and (2) each sample matrix type. Table 3 shows the acceptance criteria for each type of QC sample, and Table 5 presents the frequency of QC samples to be collected at the site.

2.8.1 Field Quality Control Requirements

Field QC samples will be collected and analyzed to assess the quality of data that are generated by sampling activities. These samples will include laboratory QC samples collected in the field, field duplicates, field blanks, equipment rinsates, MS/MDs, MS/MSDs, trip blanks, and temperature blanks. QC samples collected in the field for fixed-laboratory analysis are presented in Table 5.

Field duplicates are independent samples that are collected as close as possible, in space and time, to the original investigative sample. Field duplicates can measure the influence of sampling and field procedures on the precision of an environmental measurement. They can also provide information on the heterogeneity of a sampling location. Field duplicates will be collected at a minimum frequency of one for every 10 investigative samples, as listed in Table 5.

Immediately following collection of the original samples, the field duplicates are collected using the same collection method.

Field blanks are collected to assess: (1) impact from ambient air conditions during sample collection; (2) cross-contamination during sample collection, preservation, and shipment, as well as in the laboratory; and (3) cleanliness of the sample containers and preservatives. Field blank samples consist of sample containers filled with analytically-certified, organic-free water. Field blank samples are typically collected during ground water sample collection for VOC analysis at a frequency of one field blank for each day of ground water sampling activities (specifically for VOC analysis). Field blanks may be collected for other media and analytes as dictated by site conditions during investigative sampling activities. If a chemical is reported in a field sample and in a field blank above the MDL, it will be considered as a positive identification if the chemical is present in the field sample at a concentration greater than 5 times the maximum concentration reported in any blank.

TABLE 5 FREQUENCY OF FIELD QUALITY CONTROL SAMPLES

Field QC Sample	Frequency
Trip blank	1 per cooler containing aqueous samples for VOC analysis
Field blank	1 per day, if site conditions render this sample necessary
Field duplicate	1 per 10 samples
Equipment rinsate blank	1 per non-dedicated equipment type per day or 1 per 20 samples
MS/MD [a] (inorganics)	1 per 20 samples, or as directed by EPA
MS/MSD[a] (organics)	1 per 20 samples, or as directed by EPA
Temperature blank	1 per cooler

NOTE:

a MS, MSD, and MD analyses are technically not field QC samples; however, they generally require that the field personnel collect additional volumes of samples and are, therefore, included on this table for easy reference. The analytical laboratory will be contacted to determine sample volume requirements.

Equipment rinsate blanks are collected when non-dedicated or non-disposable sampling equipment is used to collect samples and put the samples into containers. These blanks assess the cleanliness of the sampling equipment and the effectiveness of equipment decontamination. Equipment rinsate blanks are collected by pouring analyte-free water over the decontaminated surfaces of sampling equipment that contacts sampling media. Equipment rinsate blanks are collected after sampling equipment has been decontaminated, but before the equipment is reused for sampling. If non-dedicated or non-disposable equipment is used, equipment rinsate blanks will be collected in accordance with the frequency listed in Table 5.

MS/MSD samples are laboratory QC samples that are collected for organic and inorganic methods; MS/MD samples are collected for inorganic methods. For aqueous samples, MS/MSDs may require double or triple the normal sample volume, depending on analytical laboratory specifications; MS/MDs require double the normal sample volume. In the laboratory, MS/MSD and MS/MD samples are split, and the MS/MSD are spiked with known amounts of analytes. Analytical results for MS/MSD and MS/MD samples are used to measure the precision and accuracy of the laboratory's organic and inorganic analytical programs, respectively. Each of these QC samples will be collected and analyzed at a frequency of one set for every 20 investigative samples for CLP laboratories or subcontract non-CLP laboratories, or in accordance with the requirements of the EPA Region 6 laboratory.

Trip blanks are will be analyzed for aqueous VOC samples only. VOC samples are susceptible to contamination by diffusion of organic contaminants through the Teflon™-lined septum of the sample vial; therefore, a VOC trip blank will be analyzed to monitor for possible sample contamination. Also, the trip blank will screen for possible contamination of VOC samples during handling and shipment from the field to the laboratory.

Temperature blanks are containers of deionized or distilled water that are placed in each cooler shipped to the laboratory. Their purpose is to provide a container to test the temperature of the samples in the respective cooler.

2.8.2 Laboratory Quality Control Requirements

Laboratories that perform analytical work under this project must adhere to a QA program that is used to monitor and control laboratory QC activities. Each laboratory must have a written QA Manual that describes the QA program in detail. The Laboratory QA Manager is responsible for ensuring that laboratory internal QC checks are conducted in accordance with EPA methods and protocols, the laboratory's QA Manual, and the requirements of this QAPP.

Many of the laboratory QC procedures and requirements are described in EPA-approved analytical methods, laboratory method SOPs, and method guidance documents.

The EPA methods specify the preparation and analysis of QC samples, and may include, but are not limited to, the following types: (1) LCSs; (2) method blanks; (3) MS, MSD, and MD samples; (4) surrogate spikes; and (5) standard reference materials or independent check standards. The following subsections discuss the QC checks that will be required for this project.

2.8.2.1 Laboratory Control Sample

LCSs are thoroughly characterized, laboratory-generated samples that are used to monitor the laboratory's day-to-day performance of analytical methods. The results of LCS analyses are compared to well-defined laboratory control limits to determine whether the laboratory system is in control for the particular method. If the system is not in control, corrective action will be implemented. Appropriate corrective actions will include: (1) stopping the analysis, (2) examining instrument performance or sample preparation and analysis information, and (3) determining whether samples should be re-prepared or reanalyzed.

2.8.2.2 Method Blanks

Method blanks, which are also known as preparation blanks, are analyzed to assess the level of background interference or contamination in the analytical system and the level that may lead to elevated concentration levels or false-positive data. Method blanks will be required for laboratory analyses and will be prepared and analyzed at a frequency of one method blank per every 20 samples or one method blank per batch, if the batches consist of fewer than 20 samples.

A method blank consists of reagents that are specific to the analytical method and are carried through every aspect of the analytical procedure, including sample preparation, cleanup, and analysis. The results of the method blank analysis will be evaluated in conjunction with other QC information to determine the acceptability of the data generated for that batch of samples. Ideally, the concentration of a target analyte in the method blank will be below the reporting limit or CRQL for that analyte. For some common laboratory contaminants, a higher concentration may be allowed.

If the method blank result is beyond control limits, the source of contamination must be investigated, and appropriate corrective action must be taken and documented. This investigation includes an evaluation of the data to determine the extent of the contamination and its effect on sampling results. If a method blank is within control limits but analysis indicates a concentration of analytes that is above the reporting limit, an investigation should be conducted to determine whether corrective action could eliminate an ongoing source of target analytes.

If a chemical is reported in a field sample and in a method blank, it will be considered as a positive identification if the chemical is present in the field sample at a concentration greater than 10 times (for common laboratory contaminants) or 5 times (for all other substances) the maximum concentration reported in any blank. Common laboratory contaminants include acetone, methylene chloride, methyl ethyl ketone (2-butanone), phthalate esters, and toluene.

For organic and inorganic analyses, the concentration of target analytes in the method blank must be below the reporting limit or CRQL for that analyte for the blank to be considered acceptable. An exception may be made for common laboratory contaminants (such as methylene chloride, acetone, 2-butanone, and phthalate esters) that may be present in the blank at up to five times the reporting limit. These compounds are frequently detected at low levels in method blanks from materials that are used to collect, prepare, and analyze samples for organic parameters.

2.8.2.3 Matrix Spikes

MSs and MSDs are aliquots of an environmental sample for organic analysis to which known concentrations of target analytes and compounds have been added. The MS is used to evaluate the effect of the sample matrix on the accuracy of the analysis. If there are many target analytes, they will be divided into two to three spike standard solutions. Each spike standard solution will be used alternately. The MS, in addition to an unspiked aliquot, will be taken through the entire analytical procedure, and the recovery of the analytes will be calculated. Results will be expressed in terms of percent recoveries and RPD. The percent recoveries of the target analytes and compounds are calculated and used to determine the effects of the matrix on the precision and accuracy of the method. The RPD between the MS and MSD results is used to evaluate method precision.

The MS/MSD is divided into three separate aliquots, two of which are spiked with known concentrations of target analytes. The two spiked aliquots, in addition to an unspiked sample aliquot, are analyzed separately, and the results are compared to determine the effects of the matrix on the precision and accuracy of the analysis. Results will be expressed as RPD and percent recovery and compared to control limits that have been established for each analyte. If results fall outside control limits, corrective action will be performed.

2.8.2.4 Laboratory (Matrix) Duplicates

MDs, which are also called laboratory duplicates, are prepared and analyzed for inorganic analyses to assess method precision. Two aliquots of sample material are taken from the sample and processed simultaneously without adding spiking compounds. The MD and the original sample aliquot are taken through the entire analytical procedure, and the RPD of the duplicate result is calculated. Results are expressed as RPD and are compared to control limits that have been established for each analyte.

2.8.2.5 Surrogate Spikes

Surrogates are organic compounds that are similar to the analytes of interest in chemical properties but are not normally found in environmental samples. Surrogates are added to field and QC samples, before the samples are extracted, to assess the efficacy of the extraction procedure and to assess the bias that is introduced by the sample matrix. Results are reported in terms of percent recovery. Individual analytical methods may require sample reanalysis based on surrogate criteria.

The laboratory will use surrogate recoveries mainly to assess matrix effects on sample analysis. Obvious problems with sample preparation and analysis (such as evaporation to dryness or a leaking septum) that can lead to poor surrogate spike recoveries must be eliminated before low surrogate recoveries can be attributed to matrix effects.

2.8.3 Common Data Quality Indicators

This section describes how QA objectives for precision, accuracy, completeness, and sensitivity are measured, calculated, and reported.

2.8.3.1 Precision

Precision of many analyses is assessed by comparing analytical results of MS and MSD sample pairs for organic analyses, field duplicate samples, MDs, and field replicate measurements. If precision is calculated from two measurements, it is normally measured as RPD. If precision is calculated from three or more replicates, relative standard deviation is calculated.

2.8.3.2 Accuracy

The accuracy of many analytical methods is assessed by using the results of MS and MSD samples for organic analyses, MS samples for inorganic analyses, surrogate spike samples, LCSs, standard reference materials, independent check standards, and measurements of instrument responses against zero and span gases.

For measurements in which spikes are used, percent recovery will be calculated.

2.8.3.3 Completeness

Completeness is a measure of the percentage of project-specific data that are valid. Valid data are obtained when samples are collected and analyzed in accordance with QC procedures outlined in this QAPP, and when none of the QC criteria that affect data usability are exceeded.

When data validation is completed, the percent completeness value will be calculated by dividing the number of useable results by the total number of sample results planned for this investigation.

Completeness will also be evaluated as part of the data quality assessment (DQA) process (EPA 2006c; 2006d). This evaluation will help determine whether limitations are associated with the decisions to be made based on the data collected.

2.8.3.4 Sensitivity

The achievement of MDLs depends on instrument sensitivity and matrix effects. Therefore, it is important to monitor the instrument sensitivity to ensure data quality and to ensure that analyses meet the QA objectives that have been established for sensitivity.

2.8.4 Instrument and Equipment Testing, Inspection, and Maintenance Requirements

This section outlines testing, inspection, and maintenance procedures for field equipment and instruments and for laboratory instruments.

2.8.4.1 General Requirements

Testing, inspection, and maintenance methods and frequency will be based on: (1) the type of instrument; (2) the instrument's stability characteristics; (3) the required accuracy, sensitivity, and precision of the instrument; (4) the instrument's intended use, considering project-specific DQOs; (5) manufacturer's recommendations; and (6) other conditions that affect measurement or operational control. For most instruments, preventive maintenance is performed in accordance with procedures and schedules recommended in: (1) the instrument manufacturer's literature or operating manual, or (2) SOPs associated with particular applications of the instrument.

In some cases, testing, inspection, and maintenance procedures and schedules will differ from the manufacturer's specifications or SOPs. This can occur when a field instrument is used to make critical measurements or when the analytical methods that are associated with a laboratory instrument require more frequent testing, inspection, and maintenance.

2.8.4.2 Field Equipment and Instruments

Leased field equipment and instruments will be used to conduct soil, sediment, and water sampling and preparation. The vendor will be responsible for thoroughly checking and calibrating field equipment and instruments before they are shipped or transported to the field. Copies of testing, inspection, and maintenance procedures will be shipped to the field with the equipment and instruments.

After the field equipment and instruments arrive in the field, they will be inspected for damage. Damaged equipment and instruments will be replaced or repaired immediately. Battery-operated equipment will be checked to ensure full operating capacity; if needed, batteries will be recharged or replaced.

Following use, field equipment will be decontaminated properly before being returned to the source. When the equipment is returned, copies of field notes regarding equipment problems will be included so that problems are not overlooked and necessary equipment repairs are performed.

2.8.4.3 Laboratory Instruments

Laboratories that analyze samples collected under the EPA Region 6 RAC II Program must have a preventive maintenance program that addresses: (1) testing, inspection, and maintenance procedures; and (2) the maintenance schedule for each measurement system and required support activity. This program is usually documented by a SOP for each analytical instrument that is to be used. Typically, the program will be laboratory-specific; however, it should follow requirements outlined in EPA-approved guidelines. Some of the basic requirements and components of such a program are as follows:

- As a part of its QA/QC program, each laboratory will conduct a routine preventive maintenance program to minimize instrument failure and other system malfunction.

- An internal group of qualified personnel will maintain and repair instruments, equipment, tools, and gauges. Alternatively, manufacturers' representatives may provide scheduled instrument maintenance and emergency repair under a repair and maintenance contract.

- The laboratory will perform instrument maintenance on a regularly scheduled basis. The scheduled service of critical items should minimize the downtime of the measurement system. The laboratory will prepare a list of critical spare parts for each instrument. The laboratory will request the spare parts from the manufacturer and will store the parts.

- Testing, inspection, and maintenance procedures described in laboratory SOPs will be performed in accordance with manufacturer's specifications and the requirements of the specific analytical methods that are used.

- Maintenance and service must be documented in service logbooks (or the site-specific logbook) to provide a history of maintenance records. A separate service logbook should be kept for each instrument; however, due to the limited scope of this project, the service records will be maintained in the site-specific field logbook. Maintenance records will be traceable to the specific instrument, equipment, tool, or gauge.

- The laboratory will maintain and file records that are produced as a result of tests, inspections, or maintenance of laboratory instruments. These records will be available for review by internal and external laboratory system audits that are conducted under the EPA Region 6 RAC II Program.

2.9 INSTRUMENT CALIBRATION AND FREQUENCY

This section describes the procedures for maintaining the accuracy of field equipment and laboratory instruments that are used for field tests and laboratory analyses. The equipment and instruments should be calibrated before each use or, when not in use, on a scheduled periodic basis.

2.9.1 Field Equipment

EA will perform calibration of field equipment during the site field activities specified herein. Calibration of the field equipment (multi-parameter water quality meter) will be conducted on a daily basis following manufacturer recommendations, and will be performed prior to sample analysis activities. Should water quality readings appear to be questionable during sample analysis, EA will recalibrate the equipment as deemed necessary. The equipment calibration procedures described below will be followed.

Equipment will be maintained and calibrated with sufficient frequency and in such a manner that the accuracy and reproducibility of results are consistent with the manufacturer's specifications and with project-specific DQOs. Upon arrival of the field equipment, EA field personnel will examine it to verify that it is in good working condition. The manufacturer's operating manual and instructions that accompany the equipment will be consulted to ensure that calibration procedures are followed. Measuring and testing equipment may be calibrated either internally—by using in-house reference standards—or externally—by agencies, manufacturers, or commercial laboratories. Calibration records will contain a reference identifying the source of the procedure and, where feasible, the actual procedure. Each piece of measuring and testing equipment will also be accompanied by an equipment use log. The equipment use log (which may be contained within the site-specific field logbook) will be kept current and may contain the following information: (1) date of use, (2) times of use, (3) operating and assisting technicians, (4) calibration status, and (5) comments.

2.9.2 Laboratory Instruments

Laboratory equipment that is used to analyze samples collected under the EPA Region 6 RAC II Program will be calibrated on the basis of SOPs that are maintained by the laboratory. Calibration records (including the dates and times of calibration and the names of the personnel performing the calibration) will be filed at the location at which the analytical work was performed and maintained by the laboratory personnel who performed QC activities. Subcontractor laboratories may conduct laboratory work under the EPA Region 6 RAC II Program. The laboratory QA Manager is responsible for ensuring that laboratory instruments are calibrated in accordance with the requirements of this QAPP.

The laboratories will follow the method-specific calibration procedures and requirements for laboratory measurements. Calibration procedures and requirements will also be provided, as appropriate, for laboratory support equipment, such as balances, mercury thermometers, pH meters, and other equipment that is used to take chemical and physical measurements.

2.10 REQUIREMENTS FOR INSPECTION AND ACCEPTANCE OF SUPPLIES AND CONSUMABLES

The EA Project Manager is responsible for identifying the types and quantities of supplies and consumables that are needed for collecting the samples for this Task Order. The Project Manager is also responsible for determining acceptance criteria for these items. When supplies are received, the EA field personnel will check packing slips against purchase orders and inspect the condition of supplies before the supplies are accepted for use on a project. If the supplies do not meet the acceptance criteria, deficiencies will be noted on the packing slip and purchase order. Afterward, the item will be returned to the vendor for replacement or repair.

2.11 DATA ACQUISITION REQUIREMENTS (NON-DIRECT MEASUREMENTS)

For this project, EA may acquire data from non-direct measurements (e.g., field observations for the ecological evaluation). In these instances, photographic documentation or field data sheets will be used to record the data.

Field observations are standard practice for many types of investigations (e.g., wetland delineation). These data are used in a weight of evidence approach to substantiate direct measurement data. However, these data are generally not used as the only source for a decision point.

2.12 DATA MANAGEMENT

A comprehensive data management program has been designed to assure that: (1) multiple information sources will result in similar data sets; and (2) data management practices will be adequate for the types of data processing required by a Task Order. Site team members will follow these protocols to assure results will have uniform units of measure, analytical methods, and reporting forms.

Data for this project will be obtained from a combination of sources, including field measurements, subcontracted fixed laboratories, EPA Region 6 Laboratory, and CLP laboratories. The data-gathering process requires a coordinated effort and will be conducted by project staff members in conjunction with potential data producers. The data will be obtained from the analytical service provider, when appropriate, in the form of an EDD, in addition to the required hard copy analytical data package. Formal verification (or validation) of data will be conducted before associated results are presented or are used in subsequent activities.

Data tracking is essential to ensure timely, cost-effective, and high-quality results. Data tracking begins with sample chain of custody. When the analytical service provider receives custody of the samples, the provider will send a sample acknowledgment to EA. The sample acknowledgment will confirm sample receipt, condition, and required analyses. The EPA tracking software (SCRIBE) will contain pertinent information about each sample and can track the data at each phase of the process. The tracking software carries the data through completion of the data validation.

EA will validate 10 percent of the investigative analytical data received from subcontract laboratories (other than the EPA Region 6 Laboratory or CLP laboratories) to ensure that the confirmatory data are accurate and defensible. A partial review will be conducted on the remaining 90 percent of the data received from subcontract laboratories. Data will be evaluated for usability by EA in accordance with EPA CLP guidelines for data review (EPA 2002a; 2004; 2007).

As a part of the data validation process, EDDs will be reviewed against hard copy deliverables to ensure accurate transfer of data. In addition, the hard copy will be evaluated for errors in the calculation of results. After the data validation, qualifiers can be placed on the data to indicate the usability of the data. These qualifiers will be placed into an electronic data file. Upon approval of the data set with the appropriate data qualifiers, the electronic data will be released to the Project Manager for reporting.

3. ASSESSMENT AND OVERSIGHT

This section describes the field and laboratory assessments that may be conducted during this project, the individuals responsible for conducting assessments, corrective actions that may be implemented in response to assessment results, and how quality-related issues will be reported to EA and EPA.

3.1 ASSESSMENT AND RESPONSE ACTIONS

Under the EPA Region 6 RAC II Program, performance and system audits of field and laboratory activities may be conducted to verify that sampling and analysis are performed in accordance with the following:

- Performance and system audits
  - Audit personnel
  - Audit scope of work
  - Audit frequencies
  - Audit reports.

- Corrective action
  - Sample collection and field measurements
  - Laboratory analyses.

Non-conforming items and activities are those that do not meet the project requirements, procurement document criteria, and approved work procedures. Nonconformance may be detected and identified by the following personnel:

- Project personnel—During field operations, supervision of subcontractors, and field inspections

- Testing personnel—During preparation for and performance of tests, equipment calibration, and QC activities

- QA personnel—During the performance of audits, surveillance, and other QA activities.

Each non-conformance that affects quality will be documented by the person who identifies or originates the non-conformance. Documentation of non-conformance will include the following components:

- Description of non-conformance

- Identification of personnel who are responsible for correcting the non-conformance and, if verification is required, for verifying satisfactory resolution

- Method(s) for correcting the non-conformance (corrective action) or description of the variance granted

- Proposed schedule for completing corrective action and the corrective action taken.

Non-conformance documentation will be made available to the Project Manager, QA Manager, and subcontractor (e.g., non-CLP subcontract laboratories) management personnel, as appropriate.

The field personnel and QA personnel, as appropriate, are responsible for notifying the Project Manager and the QA Manager of the non-conformance. In addition, the Project Manager and the project staff, as appropriate, will be notified of significant non-conformances that could affect the results of the work. The Project Manager is responsible for determining whether EPA notification is required.

The completion of corrective actions for significant non-conformances will be documented by QA personnel during future auditing activities. Significant recurring nonconformance will be evaluated by project and QA personnel, as appropriate, to determine its cause. Appropriate changes will be instituted, under corporate or project procedures, to prevent recurrence. When such an evaluation is performed, the results will be documented.

3.2 REPORTS TO MANAGEMENT

Effective management of environmental data collection operations requires timely assessment and review of measurement activities. It is essential that open communication, interaction, and feedback be maintained among project participants, including: (1) the EA QA Manager, Program Manager, Project Manager, technical staff, and laboratory subcontractors; and (2) the EPA Region 6 TOM and QA Officer.

During the RI field program, EA will prepare weekly reports that summarize the following elements:

- Work progress since the last weekly report
- Site observations, problems, and decisions
- Problems that may impede planned progress
- Safety-related observations, incidents, or potential safety problems and the corrective action(s) taken to mitigate the problem(s)
- Corrective measures and procedures to regain the planned schedule, if required
- QA/QC activities (e.g., number of QC samples)
- Work scheduled for the next work period.

EA prepares monthly progress reports for each Task Order that is conducted under the EPA Region 6 RAC II Program. These reports address QA issues that are specific to the Task Order and facilitate timely communication of such issues.

At the program level, the QA Manager prepares quarterly status reports of QA issues that are related to EA's work on the EPA Region 6 RAC II Program. These reports are distributed to EA's President, Corporate QA Manager, RAC II Program Manager, and, upon request, the EPA Region 6 Project Officer. QA status reports address the following areas:

- Results of QA audits and other inspections, including quality improvement; opportunities that have been identified for further action;
- Instrument, equipment, or procedural problems that affect QA;
- Subcontractor performance issues;
- Corrective actions;
- Status of previously reported activities and quality improvement initiatives; and
- Work planned for the next reporting period.

It is the Data Manager's responsibility, in consult with the Site Manager and Sample Team Leader, to direct sample collection efforts. Also, the Data Manager is responsible for assigning QA/QC samples to the appropriate media in the appropriate quantities.

There are two independent checks on the Data Manager to ensure that sample data management is adequate and to ensure that the appropriate QC samples are collected. The Sample Team Leader provides an initial check of the sampling program to ensure that the appropriate number and type of QC samples are collected. In addition, it is the Site Manger's responsibility to provide oversight and independent technical review of the sample collection efforts on a daily and weekly basis. To ensure that these two systematic checks are adequate for the field effort, a QA/QC audit will be conducted during the initial phase of the field effort.

4. DATA VALIDATION AND USABILITY

This section describes the procedures that are planned to review, verify, and validate field and laboratory data. Procedures for verifying that the data are sufficient to meet DQOs and measurement quality objectives for the project are also discussed. Section 4.1 focuses on data review and reduction requirements for work conducted under the EPA Region 6 RAC II Program. Section 4.2 addresses data validation and verification requirements. Section 4.3 addresses reconciliation with DQOs.

4.1 DATA REVIEW AND REDUCTION REQUIREMENTS

Data reduction and review are essential functions for preparing data that can be used effectively to support project decisions and DQOs. These functions must be performed accurately and in accordance with EPA-approved procedures and techniques. Data reduction includes computations and data manipulations that produce the final results that are used during the investigation. Data review includes procedures that field or laboratory personnel conduct to ensure that measurement results are correct and acceptable in accordance with the QA objectives that are stated in this QAPP. Field and laboratory measurement data reduction and review procedures and requirements are specified in previously discussed field and laboratory methods, SOPs, and guidance documents.

Field personnel will record, in a field logbook and/or on the appropriate field form, raw data from chemical and physical field measurements (SOP 016, EA 2012c). The EA field staff has the primary responsibility for: (1) verifying that field measurements were made correctly; (2) confirming that sample collection and handling procedures specified in this project-specific QAPP were followed; and (3) ensuring that field data reduction and review procedures requirements are followed. The EA field staff is also responsible for assessing preliminary data quality and for advising the data user of potential QA/QC problems with field data. If field data are used in a project report, data reduction methods will be fully documented in the report.

The EPA Region 6 Laboratory, CLP laboratory, and/or subcontracted non-CLP laboratory will complete data reduction for chemical and physical laboratory measurements and will complete an in-house review of laboratory analytical results. The Laboratory QA manager will be responsible for ensuring that laboratory data reduction and review procedures follow the requirements that are stated in this QAPP. The Laboratory QA Manager will also be responsible for assessing data quality and for advising the EA QA Manager of possible QA/QC problems with laboratory data.

4.2 VALIDATION AND VERIFICATION METHODS

Data that are used to support activities under the EPA Region 6 RAC II Program must be valid for their intended purposes. This section outlines the basic data validation procedures that will be followed for field and laboratory measurements. The following sections identify personnel who are responsible for data validation and the general data validation process and EPA data validation guidance that will be followed.

4.2.1 Data Validation Responsibilities

When analytical services are provided by laboratories subcontracted by EA, EA is responsible for data validation. The QA Manager has primary responsibility for coordinating EA's data validation activities. EA will conduct full validation on 10 percent of the subcontracted laboratory data for investigation samples. Partial validation will be conducted on the remaining 90 percent of the subcontracted laboratory data. The data validated conducted by EA will be detailed in a data validation report.

Data validation and review will be completed by one or more experienced data reviewers. When data are generated by the EPA Region 6 laboratory, it will be used as received from the laboratory, with no further validation. Data from CLP laboratories are validated by EPA's Environmental Services Assistance Team. Data validated by EPA will be summarized in a data validation report.

4.2.2 Data Validation Procedures

The validity of a data set is determined by comparing the data with a predetermined set of QC limits. EA data reviewers will conduct a systematic review of the data for compliance with established QC limits (such as sensitivity, precision, and accuracy), on the basis of spike, duplicate, and blank sampling results that are provided by the laboratory. The data review will identify out-of-control data points or omissions. EA data reviewers will evaluate laboratory data for compliance with the following information:

- Method and project-specific analytical service requests;
- Holding times;
- Initial and continuing calibration acceptance criteria;
- Field, trip, and method blank acceptance criteria;
- Surrogate recovery;
- Field duplicates and MS and MSD acceptance criteria;
- MD precision;
- LCS accuracy;
- Other laboratory QC criteria specified by the method or on the project-specific analytical service request form;
- Compound identification and quantitation; and
- Overall assessment of data, in accordance with project-specific objectives.

EA will follow the most current EPA CLP guidelines (EPA 2002a; 2004; 2007) for completing data validation for applicable test methods. General procedures in the CLP guidelines will be modified, as necessary, to fit the specific analytical method that is used to produce the data. In cases, data validation requirements will depend on: (1) DQO levels that are defined in Section 1.3; (2) reporting requirements that are defined in Section 1.4; and (3) data deliverables that are requested from the laboratory, as discussed in Section 1.6. Nevertheless, the data will be evaluated in accordance with EPA's National Functional Guidelines (2008, 2010b).

4.3 RECONCILIATION WITH DATA QUALITY OBJECTIVES

The main purpose of a QA system is to define a process for collecting data that are of known quality, are scientifically valid, are legally defensible, and fully support decisions that will be based on the data. To achieve this purpose, the QAPP requires that DQOs be fully defined (Section 1.3). Other parts of the QA system must then be planned and implemented in a manner that is consistent with the DQOs. The QA system components that follow directly from the DQOs include: (1) documentation and reporting requirements; (2) sample process design and sampling methods requirements; (3) analytical methods and analytical service requests; (4) QC requirements; and (5) data reduction and validation and reporting methods.

After environmental data have been collected, reviewed, and validated, the data will undergo a final evaluation to determine whether the DQOs specified in this QAPP have been met. EA will follow EPA's DQA process to verify that the type, quality, and quantity of data that are collected are appropriate for their intended use (EPA 2006c; 2006d).

The DQA process involves: (1) verifying that the data have met the assumptions under which the data collection design and DQOs were developed; (2) taking appropriate corrective action if the assumptions have not been met; and (3) evaluating the extent to which the data support the decision that must be made so that scientifically valid and meaningful conclusions can be drawn from the data. To the extent possible, EA will follow DQA methods and procedures that have been outlined by EPA (2006c; 2006d).

Following the conclusion of the RI field program and receipt of fixed-laboratory data, the data evaluation will include:

- Data usability evaluation and field QA/QC – The usability of the laboratory analytical data in terms of the CLP data validation summaries and field QA/QC will be evaluated.

- Data reduction and tabulation – Soil borings, field sampling data, and analytical results will be reduced and tabulated.

- DESR – A DESR will be submitted that documents and summarizes the analytical data collected during this RI/FS, including the data quality and usability as related to the site-specific DQOs. The DESR shall also include previous data collected during previous Site investigations (if made available) for statistical comparisons to the data collected during the RI/FS. Field QA/QC results will be summarized in context with fixed-laboratory sample results.

The analytical and field data will be compiled into a format that is compatible with EPA Region 6 or National Electronic Data Management Network. EA will use the data to prepare the HHRA Report, ERA Report, RI Report, ADSM, RACA Report, and FS Report, as well as to support the ROD. The specific requirements and elements of each of these reports are discussed in detail in the EPA-approved Work Plan and Cost Estimate (EA 2012a).

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FIGURES

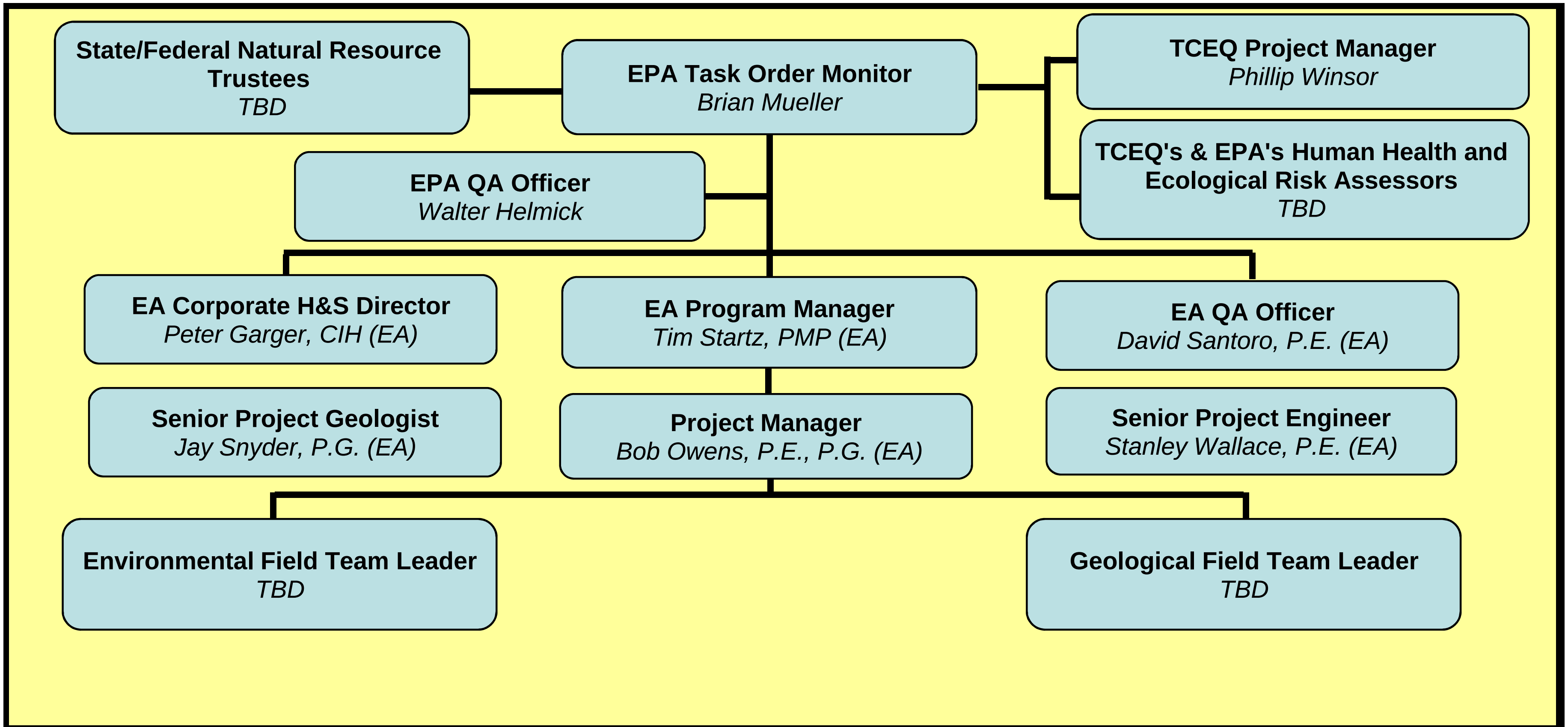

Figure 1 - Project Organization

Remedial Investigation/Feasibility Study
Falcon Refinery Superfund Site
Ingleside, San Patricio County, Texas

Source: AOC and pipeline locations from TRC, dated, March 10, 2011

Image Source: 2009 Texas Orthoimagery Program, Texas Strategic Mapping Program, TNRIS, 2009

Falcon Refinery Superfund Site
Ingleside, San Patricio County, Texas

Figure 2
Site Map
Quality Assurance Project Plan

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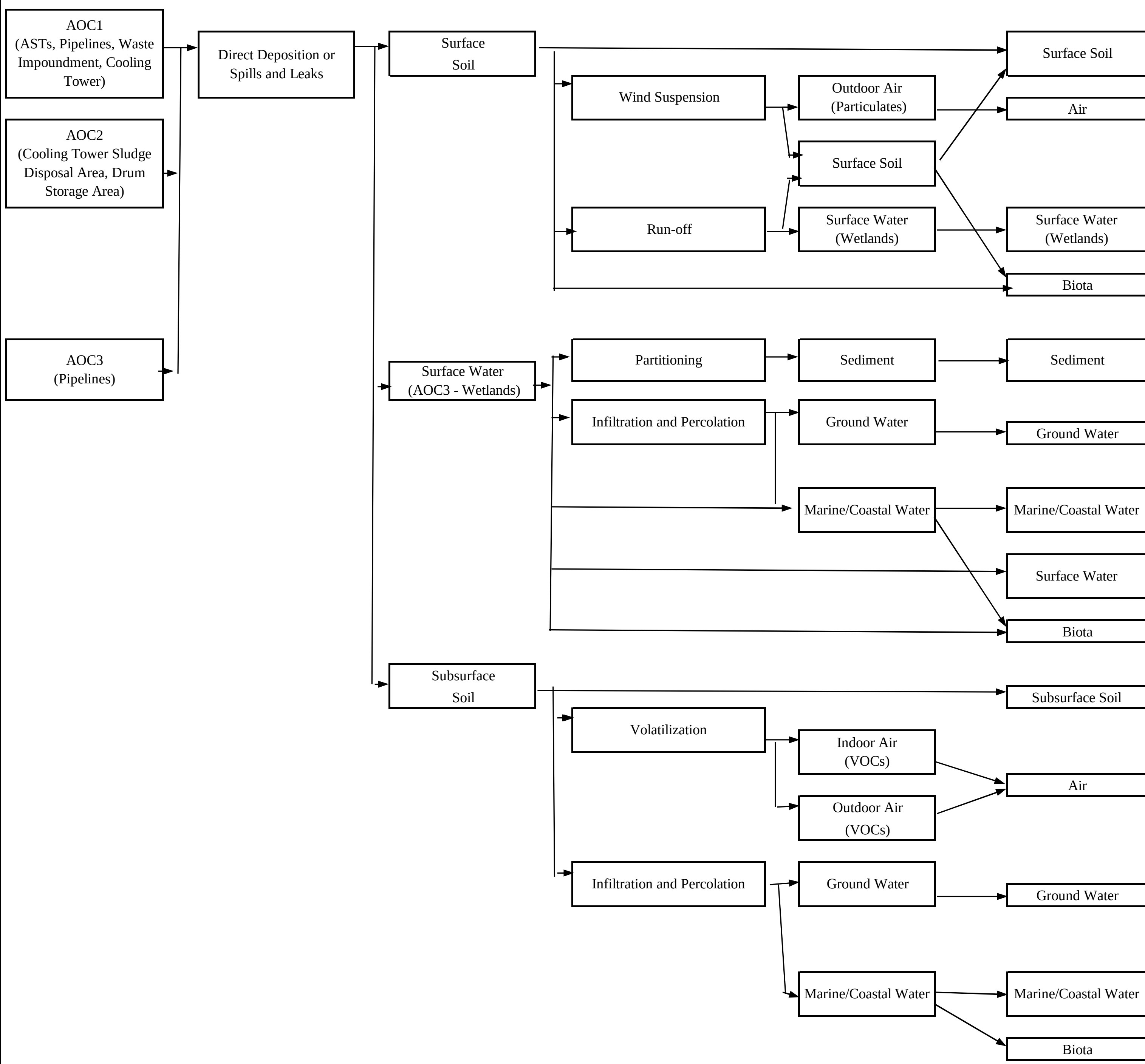
Falcon Refinery Superfund Site
Ingleside, San Patricio County,Texas

Figure 3
AOCs
Quality Assurance Project Plan

FIGURE 4
PRELIMINARY CONCEPTUAL SITE MODEL FOR AOC-1, AOC-2, AND AOC-3
FALCON REFINERY SUPERFUND SITE
INGLESIDE, TEXAS

PRIMARY SOURCE	PRIMARY RELEASE MECHANISM	SECONDARY SOURCE	SECONDARY RELEASE MECHANISM	TERTIARY SOURCE	EXPOSURE MEDIA



EXPOSURE MEDIA	EXPOSURE ROUTE	POTENTIAL HUMAN HEALTH RECEPTORS: Commercial/ Industrial Worker	Construction Worker	Recreational or Trespasser	Adult/Child Resident	POTENTIAL ECOLOGICAL RECEPTORS: Mammals & Birds	Aquatic Life	Terrestrial Invertebrates	Terrestrial Plants	Aquatic Plants
Surface Soil	Ingestion	C	C	C	C	C	I	C	I	I
	Dermal Contact	C	C	C	C	C	I	C	C	I
Air	Inhalation	C	C	C	C	I	I	I	I	I
Surface Water (Wetlands)	Ingestion	C	C	C	C	C	C	C	I	C*
	Dermal Contact	C	C	C	C	C	C	C	I	C
Biota	Ingestion	I	I	C	C	C	C	C	I	I
	Uptake	I	I	I	I	I	I	I	I	I
Sediment	Ingestion	I	C	C	C	C	C	I	I	C*
	Dermal Contact	I	C	C	C	C	C	I	I	C
Ground Water	Inhalation	C	C	C	C	I	I	I	C*	I
	Dermal Contact	C	C	C	C	I	I	I	I	I
	Ingestion	C	C	C	C	I	I	I	I	I
Marine/Coastal Water	Ingestion	C	C	C	C	C	C	I	I	C*
	Dermal Contact	C	C	C	C	C	C	I	I	C
Surface Water	Ingestion	C	C	C	C	C	C	C	I	C*
	Dermal Contact	C	C	C	C	C	C	C	I	C
Biota	Ingestion	I	I	C	C	C	C	C	I	I
	Uptake	I	I	I	I	I	I	I	I	I
Subsurface Soil	Inhalation	C	C	C	C	C	I	C	I	I
	Dermal Contact	C	C	C	C	C	I	C	I	I
Air	Inhalation	C	C	C	C	I	I	I	I	I
Ground Water	Ingestion	C	C	C	C	I	I	C*	I	I
	Dermal Contact	C	C	C	C	I	I	I	I	I
	Inhalation	C	C	C	C	I	I	I	I	I
Marine/Coastal Water	Ingestion	I	C	C	C	C	C	I	I	C*
	Dermal Contact	I	C	C	C	C	C	I	I	C
Biota	Ingestion	I	I	C	C	C	C	C	I	I
	Uptake	I	I	I	I	I	I	I	I	I

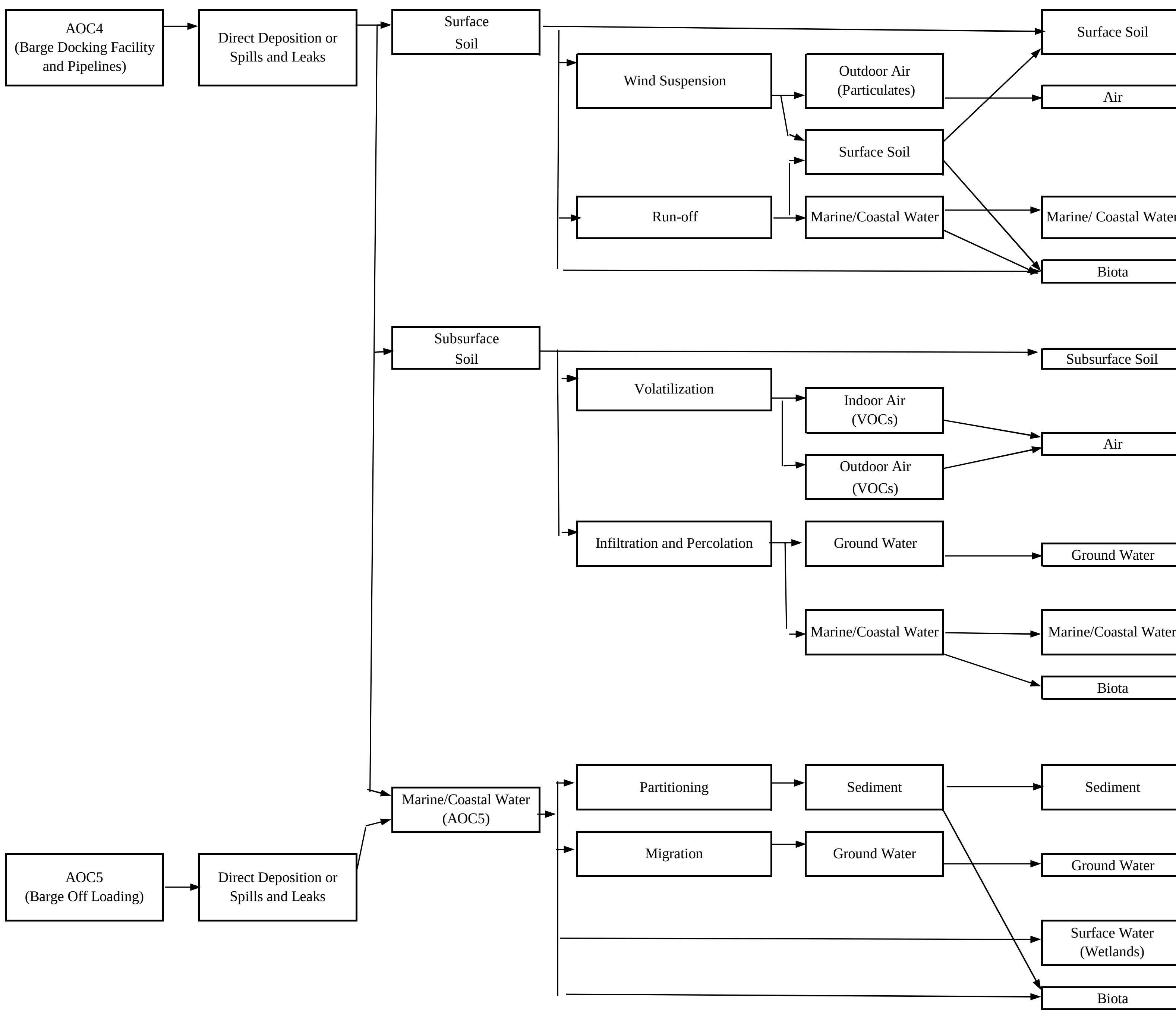
LEGEND

I	Incomplete or negligible exposure pathway
C	Potentially complete exposure pathway
*	Uptake

Conservatively current and fuure use senarios have been evaluated

FIGURE 5
PRELIMINARY CONCEPTUAL SITE MODEL AOC-4 AND AOC-5
FALCON REFINERY SUPERFUND SITE
INGLESIDE, TEXAS

PRIMARY SOURCE | PRIMARY RELEASE MECHANISM | SECONDARY SOURCE | SECONDARY RELEASE MECHANISM | TERTIARY SOURCE | EXPOSURE MEDIA | EXPOSURE ROUTE



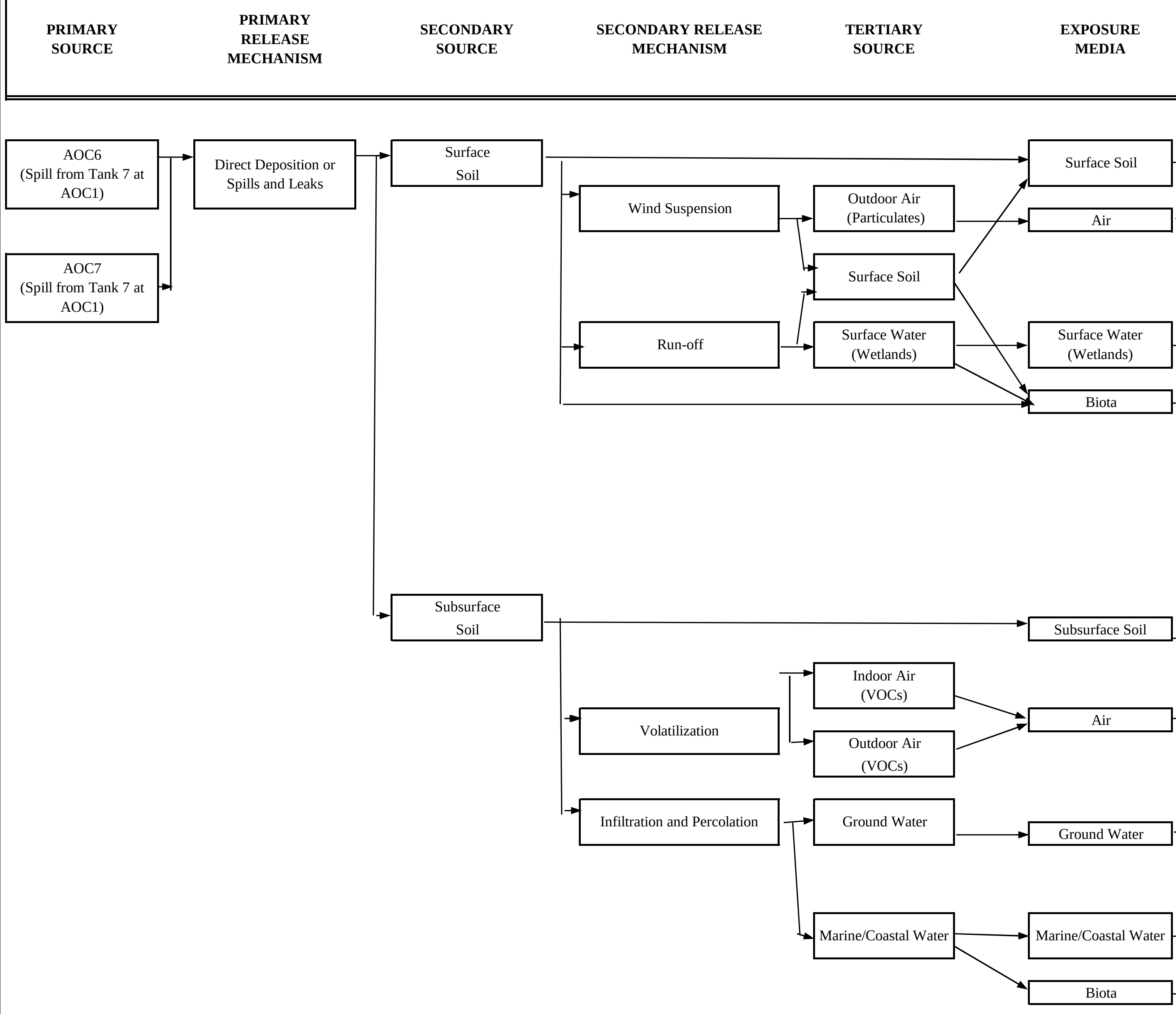
EXPOSURE MEDIA	EXPOSURE ROUTE	POTENTIAL HUMAN HEALTH RECEPTORS: Commercial/ Industrial Worker	Construction Worker	Recreational or Trespasser	Adult/Child Resident	POTENTIAL ECOLOGICAL RECEPTORS: Mammals & Birds	Aquatic Life	Terrestrial Invertebrates	Terrestrial Plants	Aquatic Plants
Surface Soil	Ingestion	C	C	C	C	C	I	C	C*	I
	Dermal Contact	C	C	C	C	C	I	C	C	I
Air	Inhalation	C	C	C	C	I	I	I	I	I
Marine/ Coastal Water	Ingestion	C	C	C	C	C	C	C*	I	C*
	Dermal Contact	C	C	C	C	C	C	C	I	C
Biota	Ingestion	I	I	C	C	C	C	C	I	I
	Uptake	I	I	I	I	I	I	I	I	I
Subsurface Soil	Inhalation	C	C	C	C	C	I	C	C*	I
	Dermal Contact	C	C	C	C	C	I	C	I	I
Air	Inhalation	C	C	C	C	I	I	I	I	I
Ground Water	Ingestion	C	C	C	C	I	I	I	C*	I
	Dermal Contact	C	C	C	C	I	I	I	I	I
	Inhalation	C	C	C	C	I	I	I	I	I
Marine/Coastal Water	Ingestion	C	C	C	C	C	C	I	I	C*
	Dermal Contact	C	C	C	C	C	C	I	I	C
Biota	Ingestion	I	I	C	C	C	C	C	I	I
	Uptake	I	I	I	I	I	I	I	I	I
Sediment	Ingestion	I	C	C	C	C	C	I	I	C*
	Dermal Contact	I	C	C	C	C	C	I	I	C
Ground Water	Inhalation	I	C	C	C	I	I	I	I	I
	Dermal Contact	I	C	C	C	I	I	I	I	I
	Ingestion	I	C	C	C	I	I	I	I	I
Surface Water (Wetlands)	Dermal Contact	I	C	C	C	C	C	C	I	C*
	Ingestion	I	C	C	C	C	C	C	I	C
Biota	Ingestion	I	I	C	C	C	C	I	I	I
	Uptake	I	I	I	I	I	I	I	I	I

LEGEND

I — Incomplete or negligible exposure pathway
C — Potentially complete exposure pathway
* — Uptake

Conservatively current and fuure use senarios have been evaluated

FIGURE 6
PRELIMINARY CONCEPTUAL SITE MODEL FOR AOC-6 AND AOC-7
FALCON REFINERY SUPERFUND SITE
INGLESIDE, TEXAS



EXPOSURE MEDIA	EXPOSURE ROUTE	POTENTIAL HUMAN HEALTH RECEPTORS: Commercial/ Industrial Worker	Construction Worker	Recreational or Trespasser	Adult/Child Resident	POTENTIAL ECOLOGICAL RECEPTORS: Mammals & Birds	Aquatic Life	Terrestrial Invertabrets	Terrestrial Plants	Aquatic Plants
Surface Soil	Ingestion	C	C	C	C	C	I	C	C*	I
	Dermal Contact	C	C	C	C	C	I	C	C	I
Air	Inhalation	C	C	C	C	I	I	I	I	I
Surface Water (Wetlands)	Ingestion	C	C	C	C	C	C	C	I	C*
	Dermal Contact	C	C	C	C	C	C	C	I	C
Biota	Ingestion	I	I	C	C	C	C	C	I	I
	Uptake	I	I	I	I	I	I	I	I	I
Subsurface Soil	Inhalation	C	C	C	C	C	I	C	C*	I
	Dermal Contact	C	C	C	C	C	I	C	I	I
Air	Inhalation	C	C	C	C	I	I	I	I	I
Ground Water	Ingestion	C	C	C	C	I	I	I	C*	I
	Dermal Contact	C	C	C	C	I	I	I	I	I
	Inhalation	C	C	C	C	I	I	I	I	I
Marine/Coastal Water	Dermal Contact	C	C	C	C	C	C	I	I	C*
	Ingestion	C	C	C	C	C	C	I	I	C
Biota	Ingestion	I	I	C	C	C	C	C	I	I
	Uptake	I	I	I	I	I	I	I	I	I

LEGEND

I Incomplete or negligible exposure pathway
C Potentially complete exposure pathway
* Uptake

Conservatively current and fuure use senarios have been evaluated

Appendix A

TABLE A-1. REFERENCE LIMITS AND PROJECT ACTION LIMITS FOR GROUNDWATER
FALCON REFINERY SUPERFUND SITE

Analyte	CASRN	Units	c/nc	MCL[1]	TCEQ Residential $^{GW}GW_{Ing}$2	USEPA Tapwater RSL[3]	PAL[7]	Analytical Method	Achievable Laboratory Limits (TestAmerica, Tacoma) LOQ	LOD	DL	Analytical Method	Achievable Laboratory Limits (Accutest) LOQ	LOD	DL	Analytical Method	Achievable Laboratory Limits (BC Laboratories) LOQ	LOD	DL
Volatile Organic Compounds																			
Acetone	67-64-1	µg/L	nc	NS		12,000	0	SW8260B	10	4.5	1.7	SW8260B	20	10	4.0	SW8260B	10	5.0	4.6
Benzene	71-43-2	µg/L	c	5.0		0.39	0.39	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.40	0.20	SW8260B	0.50	0.16	0.083
Bromobenzene	108-86-1	µg/L	nc	NS		54	54	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.40	0.20	SW8260B	0.50	0.16	0.13
Bromochloromethane	74-97-5	µg/L	nc	NS		83	70	SW8260B	1.0	0.70	0.24	SW8260B	1.0	0.40	0.20	SW8260B	1.0	0.30	0.24
Bromodichloromethane	75-27-4	µg/L	c	NS		0.12	0.12	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.40	0.20	SW8260B	0.50	0.30	0.14
Bromoform	75-25-2	µg/L	c	NS		7.9	7.9	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.50	0.22	SW8260B	0.60	0.30	0.27
Bromomethane (Methyl bromide)	74-83-9	µg/L	nc	NS		7.0	1.7	SW8260B	5.0	2.3	0.75	SW8260B	2.0	0.40	0.20	SW8260B	0.60	0.25	0.25
2-Butanone (Methyl ethyl ketone)	78-93-3	µg/L	nc	NS		4,900	0	SW8260B	10	4.5	1.5	SW8260B	10	4.0	2.0	SW8260B	10	3.0	2.5
n-Butylbenzene	104-51-8	µg/L	nc	NS		780	28	SW8260B	1.0	0.45	0.15	SW8260B	2.0	0.40	0.20	SW8260B	0.50	0.16	0.11
sec-Butylbenzene	135-98-8	µg/L	nc	NS	980	NS	25	SW8260B	1.0	0.45	0.15	SW8260B	2.0	0.40	0.20	SW8260B	0.50	0.16	0.15
t-Butylbenzene	98-06-6	µg/L	nc	NS	980	NS	34	SW8260B	1.0	0.45	0.15	SW8260B	2.0	0.50	0.28	SW8260B	0.50	0.16	0.13
Carbon disulfide	75-15-0	µg/L	nc	NS		720	124	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.40	0.20	SW8260B	1.0	0.40	0.38
Carbon tetrachloride	56-23-5	µg/L	c	5.0		0.39	0.36	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.40	0.20	SW8260B	0.50	0.20	0.18
Chlorobenzene	108-90-7	µg/L	nc	100		72	10	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.40	0.20	SW8260B	0.50	0.16	0.093
Chloroethane (Ethyl chloride)	75-00-3	µg/L	nc	NS		21,000	29	SW8260B	5.0	2.3	0.75	SW8260B	1.0	0.40	0.20	SW8260B	0.50	0.16	0.14
Chloroform	67-66-3	µg/L	c	NS		0.19	0.19	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.40	0.20	SW8260B	0.50	0.16	0.12
Chloromethane (Methyl chloride)	74-87-3	µg/L	nc	NS		190	6.6	SW8260B	5.0	2.3	0.75	SW8260B	1.0	0.40	0.20	SW8260B	0.50	0.16	0.14
2-Chlorotoluene	95-49-8	µg/L	nc	NS		180	180	SW8260B	1.0	0.45	0.15	SW8260B	2.0	0.40	0.20	SW8260B	0.50	0.20	0.20
4-Chlorotoluene	106-43-4	µg/L	nc	NS		190	190	SW8260B	1.0	0.45	0.15	SW8260B	2.0	0.50	0.26	SW8260B	0.50	0.16	0.15
1,2-Dibromo-3-chloropropane (DBCP)	96-12-8	µg/L	c	0.20		0.00032	0.00032	SW8011/ SW8260B	0.010	0.0030	0.0030	SW8260B	2.0	1.0	0.40	504.1	1.0	0.50	0.44
Dibromochloromethane (Chlorodibromomethane)	124-48-1	µg/L	c	NS		0.15	0.15	SW8260B	1.0	0.90	0.32	SW8260B	1.0	0.40	0.20	SW8260B	0.50	0.16	0.13
1,2-Dibromoethane (Ethylene dibromide [EDB])	106-93-4	µg/L	c	0.050		0.0065	0.0050	SW8011	0.010	0.0030	0.0020	SW8011	0.020	0.010	0.010	SW8011	0.010	0.0050	0.0013
Dibromomethane (Methylene bromide)	74-95-3	µg/L	nc	NS		7.9	7.9	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.40	0.20	SW8260B	1.0	0.30	0.24
1,2-Dichlorobenzene	95-50-1	µg/L	nc	600		280	60	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.50	0.20	SW8260B	0.50	0.16	0.072
1,3-Dichlorobenzene	541-73-1	µg/L	nc	NS	730	NS	194	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.40	0.20	SW8260B	0.50	0.16	0.15
1,4-Dichlorobenzene	106-46-7	µg/L	c	75		0.42	0.42	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.40	0.20	SW8260B	0.50	0.16	0.062
Dichlorodifluoromethane	75-71-8	µg/L	nc	NS		190	0.71	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.40	0.20	SW8260B	0.50	0.16	0.099
1,1-Dichloroethane	75-34-3	µg/L	c	NS		2.4	2.4	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.40	0.20	SW8260B	0.50	0.16	0.11
1,2-Dichloroethane	107-06-2	µg/L	c	5.0		0.15	0.15	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.40	0.20	SW8260B	0.50	0.20	0.17
1,1-Dichloroethene	75-35-4	µg/L	c	7.0		260	0.70	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.40	0.20	SW8260B	0.50	0.20	0.18
1,2-Dichloroethene (cis)	156-59-2	µg/L	nc	70		28	4.4	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.40	0.20	SW8260B	0.50	0.16	0.085
1,2-Dichloroethene (trans)	156-60-5	µg/L	nc	100		86	10	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.40	0.20	SW8260B	0.50	0.16	0.15
1,2-Dichloropropane	78-87-5	µg/L	c	5.0		0.38	0.38	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.40	0.20	SW8260B	0.50	0.16	0.13
1,3-Dichloropropane	142-28-9	µg/L	nc	NS		290	290	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.40	0.20	SW8260B	0.50	0.16	0.086
2,2-Dichloropropane	594-20-7	µg/L	-	NS	13	NS	NS	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.40	0.20	SW8260B	0.50	0.16	0.13
1,1-Dichloropropene	563-58-6	µg/L	-	NS	9.1	NS	NS	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.40	0.20	SW8260B	0.50	0.16	0.085
1,3-Dichloropropene (cis)	10061-01-5	µg/L	-	NS	1.7	NS	NS	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.40	0.20	SW8260B	0.50	0.16	0.14
1,3-Dichloropropene (trans)	10061-02-6	µg/L	-	NS	9.1	NS	NS	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.50	0.30	SW8260B	0.50	0.16	0.079
1,3-Dichloropropene (total)	542-75-6	µg/L	c	NS		0.41	0.41	SW8260B	2.0	0.90	0.30	SW8260B	2.0	0.90	0.50	SW8260B	1.0	0.33	0.21
Ethylbenzene	100-41-4	µg/L	c	700		1.3	1.3	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.40	0.20	SW8260B	0.50	0.16	0.098
Hexachlorobutadiene	87-68-3	µg/L	c	NS		0.26	0.26	SW8260B	1.0	0.45	0.15	SW8260B	2.0	0.40	0.20	SW8260B	0.50	0.20	0.17
2-Hexanone	591-78-6	µg/L	nc	NS		34	34	SW8260B	5.0	2.3	0.75	SW8260B	10	4.0	2.0	SW8260B	10	4.0	3.4
Isopropylbenzene (Cumene)	98-82-8	µg/L	nc	NS		390	89	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.40	0.20	SW8260B	0.50	0.16	0.14
p-Isopropyltoluene	99-87-6	µg/L	-	NS	2,400	NS	NS	SW8260B	1.0	0.45	0.15	SW8260B	2.0	0.40	0.20	SW8260B	0.50	0.16	0.12
4-Methyl-2-pentanone (Methyl isobutyl ketone [MIBK])	108-10-1	µg/L	nc	NS		1,000	290	SW8260B	5.0	2.3	0.75	SW8260B	10	4.0	1.0	SW8260B	10	3.0	2.1
Methylene chloride	75-09-2	µg/L	c	5.0		9.9	0.50	SW8260B	3.0	0.45	0.15	SW8260B	5.0	4.0	2.0	SW8260B	1.0	0.50	0.48
Methyl-tertiary-butyl ether (MtBE)	1634-04-4	µg/L	c	NS		12	12	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.40	0.20	SW8260B	0.50	0.16	0.11
Naphthalene	91-20-3	µg/L	nc	NS		0.14	0.14	SW8260B	1.0	0.45	0.15	SW8260B	5.0	2.0	0.50	SW8260B	0.50	0.40	0.36
n-Propylbenzene	103-65-1	µg/L	nc	NS		530	37	SW8260B	1.0	0.45	0.15	SW8260B	2.0	0.40	0.20	SW8260B	0.50	0.16	0.11
Styrene	100-42-5	µg/L	nc	100		1,100	10	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.40	0.20	SW8260B	0.50	0.16	0.068
1,1,1,2-Tetrachloroethane	630-20-6	µg/L	c	NS		0.50	0.50	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.50	0.30	SW8260B	0.50	0.16	0.18
1,1,2,2-Tetrachloroethane	79-34-5	µg/L	c	NS		0.066	0.066	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.40	0.20	SW8260B	0.50	0.20	0.17
Tetrachloroethene (PCE)	127-18-4	µg/L	c	5.0		9.7	0.50	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.50	0.30	SW8260B	0.50	0.16	0.13
Toluene	108-88-3	µg/L	nc	1,000		860	100	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.40	0.20	SW8260B	0.50	0.16	0.093
1,2,3-Trichlorobenzene	87-61-6	µg/L	nc	NS		5.2	5.2	SW8260B	1.0	0.45	0.15	SW8260B	2.0	0.40	0.20	SW8260B	0.50	0.16	0.16
1,2,4-Trichlorobenzene	120-82-1	µg/L	nc	70		0.99	0.99	SW8260B	1.0	0.45	0.15	SW8260B	2.0	0.40	0.20	SW8260B	0.50	0.20	0.19
1,1,1-Trichloroethane	71-55-6	µg/L	nc	200		7,500	20	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.40	0.20	SW8260B	0.50	0.16	0.11
1,1,2-Trichloroethane	79-00-5	µg/L	c	5.0		0.24	0.24	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.40	0.22	SW8260B	0.50	0.16	0.16
Trichloroethene (TCE)	79-01-6	µg/L	nc	5.0		0.44	0.44	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.40	0.20	SW8260B	0.50	0.16	0.085
Trichlorofluoromethane	75-69-4	µg/L	nc	NS		1,100	18	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.40	0.20	SW8260B	0.50	0.16	0.13
1,2,3-Trichloropropane	96-18-4	µg/L	c	NS		0.00065	0.00065	SW8260B	1.0	0.45	0.15	SW8260B	2.0	0.40	0.20	SW8260B	1.0	0.33	0.24
1,2,4-Trimethylbenzene	95-63-6	µg/L	nc	NS		15	2.9	SW8260B	1.0	0.45	0.15	SW8260B	2.0	0.40	0.20	SW8260B	0.50	0.16	0.12
1,3,5-Trimethylbenzene	108-67-8	µg/L	nc	NS		87	2.0	SW8260B	1.0	0.45	0.15	SW8260B	2.0	0.40	0.20	SW8260B	0.50	0.16	0.12
Vinyl chloride	75-01-4	µg/L	c	2.0		0.015	0.015	SW8260B	1.0	0.45	0.15	SW8260B	1.0	0.40	0.20	SW8260B	0.50	0.16	0.12
m- & p-Xylenes	179601-23-1	µg/L	-	NS		NS	35	SW8260B	2.0	0.90	0.30	SW8260B	2.0	1.2	0.46	SW8260B	0.50	0.30	0.28
o-Xylene	95-47-6	µg/L	-	NS		190	47	SW8260B	1.0	0.45	0.15	SW8260B	2.0	1.2	0.46	SW8260B	0.50	0.16	0.082
Xylenes (total)	1330-20-7	µg/L	nc	10,000		190	38	SW8260B	3.0	1.4	0.45	SW8260B	2.0	1.2	0.46	SW8260B	1.0	0.46	0.36
Semivolatile Organic Compounds																			
Benzoic acid	65-85-0	µg/L	nc	NS		58,000	15,000	SW8270C	10	5.0	3.0	SW8270C	20	10	4.0	SW8270C	20	6.0	5.8
Benzyl alcohol	100-51-6	µg/L	-	NS		1,500	1,500	SW8270C	2.0	1.0	0.50	SW8270C	5.0	2.0	1.7	SW8270C	4.0	1.0	0.34
Bis(2-chloroethoxy)methane	111-91-1	µg/L	-	NS		47	47	SW8270C	2.0	1.0	0.50	SW8270C	5.0	2.0	1.1	SW8270C	4.0	1.0	0.27
Bis(2-chloroethyl)ether	111-44-4	µg/L	c	NS		0.012	0.012	SW8270C	2.0	1.0	0.50	SW8270C	5.0	2.0	1.1	SW8270C	4.0	1.0	0.68
Bis(2-chloroisopropyl) ether	108-60-1	µg/L	c	NS		0.31	0.31	SW8270C	2.0	1.0	0.50	SW8270C	5.0	2.0	1.0	SW8270C	4.0	1.0	0.30
Bis(2-ethylhexyl) phthalate	117-81-7	µg/L	c	6.0		0.071	0.071	SW8270C	15	10	5.9	SW8270C	10	4.0	2.0	SW8270C	8.0	4.0	3.0
4-Bromophenyl phenyl ether	101-55-3	µg/L	-	NS	0.061	NS	NS	SW8270C	2.0	1.0	0.50	SW8270C	5.0	2.0	1.5	SW8270C	4.0	1.0	0.23
Butyl benzyl phthalate	85-68-7	µg/L	c	NS		14	14	SW8270C	3.0	1.0	1.0	SW8270C	5.0	2.0	1.2	SW8270C	4.0	1.0	0.47
Carbazole	86-74-8	µg/L	c	NS	46	NS	4.3	SW8270C	2.0	1.0	0.50	SW8270C	5.0	2.0	1.5	SW8270C	4.0	1.0	0.20
4-Chloro-3-methylphenol	59-50-7	µg/L	nc	NS		1,100	1,100	SW8270C	2.0	1.0	0.50	SW8270C	5.0	2.0	1.4	SW8270C	10	3.0	0.40
4-Chloroaniline	106-47-8	µg/L	c	NS		0.32	0.32	SW8270C	2.0	1.0	0.50	SW8270C	5.0	2.0	1.1	SW8270C	4.0	1.0	0.69
2-Chloronaphthalene	91-58-7	µg/L	nc	NS		550	290	SW8270C	0.30	0.15	0.10	SW8270C	5.0	2.0	1.4	SW8270C	4.0	1.0	0.34
2-Chlorophenol	95-57-8	µg/L	nc	NS		71	18	SW8270C	2.0	1.0	0.50	SW8270C	5.0	2.0	1.4	SW8270C	4.0	1.0	0.37
4-Chlorophenyl phenyl ether	7005-72-3	µg/L	-	NS	0.061	NS	NS	SW8270C	2.0	1.0	0.50	SW8270C	5.0	2.0	1.5	SW8270C	4.0	1.0	0.23
Dibenzofuran	132-64-9	µg/L	nc	NS		5.8	5.8	SW8270C	2.0	1.0	0.50	SW8270C	5.0	2.0	1.4	SW8270C	4.0	1.0	0.21
3,3-Dichlorobenzidine	91-94-1	µg/L	c	NS		0.11	0.11	SW8270C	10	1.0	0.50	SW8270C	10	4.0	2.0	SW8270C	20	10	8.2
2,4-Dichlorophenol	120-83-2	µg/L	nc	NS		35	11	SW8270C	2.0	1.0	0.50	SW8270C	5.0	2.0	1.2	SW8270C	4.0	1.0	0.43
Diethyl phthalate	84-66-2	µg/L	nc	NS		11,000	2,900	SW8270C	2.0	1.0	0.50	SW8270C	5.0	2.0	1.1	SW8270C	4.0	1.0	0.33
2,4-Dimethylphenol	105-67-9	µg/L	nc	NS		270	73	SW8270C	10	2.0	1.5	SW8270C	5.0	2.0	1.1	SW8270C	4.0	1.0	0.20
4,6-Dinitro-2-methylphenol	534-52-1	µg/L	-	NS		1.2	1.2	SW8270C	20	10	5.0	SW8270C	10	2.0	1.3	SW8270C	20	6.0	0.34
2,4-Dinitrophenol	51-28-5	µg/L	nc	NS		30	7.3	SW8270C	25	10	5.0	SW8270C	20	10	4.0	SW8270C	20	6.0	0.20
2,4-Dinitrotoluene	121-14-2	µg/L	nc	NS		0.20	0.13	SW8270C	2.0	1.0	0.50	SW8270C	5.0	2.0	1.3	SW8270C	4.0	1.0	0.26
2,6-Dinitrotoluene	606-20-2	µg/L	c	NS		15	0.13	SW8270C	2.0	1.0	0.50	SW8270C	5.0	2.0	1.2	SW8270C	4.0	1.0	0.41
Dimethyl phthalate	131-11-3	µg/L	nc	NS	20,000	NS	37,000	SW8270C	2.0	1.0	0.50	SW8270C	5.0	2.0	1.8	SW8270C	4.0	1.0	0.39
Di-n-butyl phthalate	84-74-2	µg/L	nc	NS		670	370	SW8270C	2.0	1.0	0.65	SW8270C	5.0	2.0	1.4	SW8270C	4.0	1.0	0.39
Di-n-octyl phthalate	117-84-0	µg/L	nc	NS	980	NS	150	SW8270C	2.0	1.0	1.0	SW8270C	5.0	2.0	1.8	SW8270C	4.0	1.0	0.46
Hexachlorobenzene	118-74-1	µg/L	c	1.0		0.042	0.042	SW8270C	2.0	1.0	0.50	SW8270C	5.0	2.0	1.4	SW8270C	4.0	1.0	0.20
Hexachlorocyclopentadiene	77-47-4	µg/L	nc	50		22	5.0	SW8270C	10	1.0	0.50	SW8270C	5.0	2.0	1.0	SW8270C	4.0	1.0	0.30
Hexachloroethane	67-72-1	µg/L	c	NS		0.79	0.79	SW8270C	3.0	1.0	0.50	SW8270C	5.0	2.0	1.2	SW8270C	4.0	1.0	0.32
Isophorone	78-59-1	µg/L	c	NS		67	67	SW8270C	2.0	1.0	0.50	SW8270C	5.0	2.0	1.1	SW8270C	4.0	1.0	0.31
2-Methylphenol	95-48-7	µg/L	c	NS		720	180	SW8270C	2.0	1.0	0.50	SW8270C	5.0	2.0	1.7	SW8270C	4.0	1.0	1.0
3- & 4-Methylphenols	15831-10-4	µg/L	c	NS		720	18	SW8270C	4.0	1.0	0.50	SW8270C	10	2.0	1.6	SW8270C	4.0	2.0	1.6
2-Nitroaniline	88-74-4	µg/L	nc	NS		150	150	SW8270C	2.0	1.0	0.50	SW8270C	5.0	2.0	1.1	SW8270C	4.0	1.0	0.33
3-Nitroaniline	99-09-2	µg/L	-	NS	7.3	NS	NS	SW8270C	2.0	1.0	0.60	SW8270C	5.0	2.0	1.3	SW8270C	4.0	1.0	0.66
4-Nitroaniline	100-01-6	µg/L	c	NS		3.3	3.3	SW8270C	3.0	1.0	0.50	SW8270C	5.0	2.0	1.1	SW8270C	10	3.0	0.87
Nitrobenzene	98-95-3	µg/L	c	NS		0.12	0.12	SW8270C	2.0	1.0	0.50	SW8270C	5.0	2.0	1.0	SW8270C	4.0	1.0	0.26
2-Nitrophenol	88-75-5	µg/L	-	NS	49	NS	NS	SW8270C	2.0	1.0	0.50	SW8270C	5.0	2.0	1.0	SW8270C	4.0	1.0	0.28
4-Nitrophenol	100-02-7	µg/L	-	NS	49	NS	NS	SW8270C	10	10	5.0	SW8270C	10	4.0	1.0	SW8270C	4.0	1.0	0.73
N-Nitrosodimethylamine	62-75-9	µg/L	c	NS		0.00042	0.00042	SW8270C	10	2.5	1.0	SW8270C	5.0	2.0	1.0	SW8270C	4.0	1.0	0.61
N-Nitrosodi-n-propylamine	621-64-7	µg/L	c	NS		0.0093	0.0093	SW8270C	2.0	1.0	0.50	SW8270C	5.0	2.0	1.1	SW8270C	4.0	1.0	1.3
N-Nitrosodiphenylamine	86-30-6	µg/L	c	NS		10	10	SW8270C	2.0	1.0	0.50	SW8270C	5.0	2.0	1.4	SW8270C	4.0	1.0	0.44
Pentachlorophenol	87-86-5	µg/L	c	1.0		0.17	0.10	SW8270C	3.5	1.0	0.50	SW8270C	10	4.0	1.7	SW8270C	20	6.0	0.79
Phenol	108-95-2	µg/L	nc	NS		4,500	1,100	SW8270C	3.0	1.0	0.50	SW8270C	5.0	2.0	1.0	SW8270C	4.0	1.0	0.20
1,2,4-Trichlorobenzene	120-82-1	µg/L	nc	70		0.99	0.99	SW8270C	2.0	1.0	0.50	SW8270C	5.0	2.0	1.2	SW8270C	4.0	1.0	0.27
2,4,5-Trichlorophenol	95-95-4	µg/L	nc	NS		890	370	SW8270C	2.0	1.0	0.50	SW8270C	5.0	2.0	1.0	SW8270C	10	3.0	0.31
2,4,6-Trichlorophenol	88-06-2	µg/L	c	NS		3.5	3.5	SW8270C	3.0	1.0	0.50	SW8270C	5.0	2.0	1.0	SW8270C	10	3.0	0.60
Polycyclic Aromatic Hydrocarbons																			
Acenaphthene	83-32-9	µg/L	nc	NS		400	220	SW8270C SIM	0.10	0.075	0.030	SW8270C SIM	0.50	0.10	0.050	SW8270C SIM	0.10	0.030	0.014
Acenaphthylene	208-96-8	µg/L	nc	NS	1,500	NS	220	SW8270C SIM	0.10	0.075	0.030	SW8270C SIM	0.50	0.10	0.050	SW8270C SIM	0.10	0.030	0.021
Anthracene	120-12-7	µg/L	nc	NS		1,300	1,100	SW8270C SIM	0.10	0.075	0.030	SW8270C SIM	0.50	0.10	0.050	SW8270C SIM	0.10	0.030	0.022
Benzo(a)anthracene	56-55-3	µg/L	c	NS		0.029	0.029	SW8270C SIM	0.10	0.075	0.030	SW8270C SIM	0.10	0.10	0.053	SW8270C SIM	0.10	0.040	0.032
Benzo(b)fluoranthene	205-99-2	µg/L	c	NS		0.029	0.029	SW8270C SIM	0.10	0.075	0.030	SW8270C SIM	0.10	0.10	0.035	SW8270C SIM	0.10	0.030	0.022
Benzo(k)fluoranthene	207-08-9	µg/L	c	NS		0.29	0.29	SW8270C SIM	0.10	0.075	0.030	SW8270C SIM	0.10	0.10	0.039	SW8270C SIM	0.10	0.030	0.021
Benzo(g,h,i)perylene	191-24-2	µg/L	nc	NS	730	NS	110	SW8270C SIM	0.10	0.075	0.030	SW8270C SIM	0.10	0.10	0.036	SW8270C SIM	0.10	0.030	0.021
Benzo(a)pyrene	50-32-8	µg/L	c	0.20		0.0029	0.0029	SW8270C SIM	0.20	0.075	0.030	SW8270C SIM	0.10	0.10	0.041	SW8270C SIM	0.10	0.030	0.019
Chrysene	218-01-9	µg/L	c	NS		2.9	2.9	SW8270C SIM	0.10	0.075	0.030	SW8270C SIM	0.10	0.10	0.045	SW8270C SIM	0.10	0.030	0.010
Dibenz(a,h)anthracene	53-70-3	µg/L	c	NS		0.0029	0.0029	SW8270C SIM	0.10	0.075	0.030	SW8270C SIM	0.10	0.10	0.035	SW8270C SIM	0.10	0.030	0.028
Fluoranthene	206-44-0	µg/L	nc	NS		630	150	SW8270C SIM	0.10	0.075	0.030	SW8270C SIM	0.50	0.10	0.050	SW8270C SIM	0.10	0.030	0.010
Fluorene	86-73-7	µg/L	nc	NS		220	150	SW8270C SIM	0.10	0.075	0.030	SW8270C SIM	0.50	0.10	0.050	SW8270C SIM	0.10	0.030	0.010
Indeno(1,2,3-cd)pyrene	193-39-5	µg/L	c	NS		0.029	0.029	SW8270C SIM	0.10	0.075	0.030	SW8270C SIM	0.10	0.10	0.035	SW8270C SIM	0.10	0.030	0.026
1-Methylnaphthalene	90-12-0	µg/L	c	NS		0.97	0.97	SW8270C SIM	0.10	0.075	0.030	SW8270C SIM	0.50	0.10	0.10	SW8270C SIM	not included in current suite		
2-Methylnaphthalene	91-57-6	µg/L	nc	NS		27	15	SW8270C SIM	0.13	0.075	0.030	SW8270C SIM	0.50	0.10	0.10	SW8270C SIM	0.10	0.030	0.0087
Naphthalene	91-20-3	µg/L	c	NS		0.14	0.14	SW8270C SIM	0.10	0.075	0.036	SW8270C SIM	0.50	0.10	0.10	SW8270C SIM	0.10	0.030	0.010
Phenanthrene	85-01-8	µg/L	nc	NS	730	NS	1,100	SW8270C SIM	0.10	0.075	0.030	SW8270C SIM	0.50	0.10	0.050	SW8270C SIM	0.10	0.030	0.020
Pyrene	129-00-0	µg/L	nc	NS		87	87	SW8270C SIM	0.10	0.075	0.030	SW8270C SIM	0.50	0.10	0.050	SW8270C SIM	0.10	0.030	0.020
Organochlorine Pesticides																			
Aldrin	309-00-2	µg/L	c	NS		0.00021	0.00021	SW8081A	0.010	0.0050	0.0030	SW8081A	0.010	0.0040	0.0020	SW8081A	0.010	0.0030	0.0013
alpha-BHC	319-84-6	µg/L	c	NS		0.0062	0.0062	SW8081A	0.010	0.0030	0.0026	SW8081A	0.010	0.0040	0.0026	SW8081A	0.010	0.0030	0.0011
beta-BHC	319-85-7	µg/L	c	NS		0.022	0.022	SW8081A	0.020	0.0030	0.0015	SW8081A	0.010	0.0050	0.0045	SW8081A	0.010	0.0030	0.0021
delta-BHC	319-86-8	µg/L	c	NS	0.51	NS	NS	SW8081A	0.010	0.0050	0.0030	SW8081A	0.010	0.0040	0.0033	SW8081A	0.010	0.0030	0.0014
gamma-BHC (Lindane)	58-89-9	µg/L	c	0.20		0.036	0.020	SW8081A	0.010	0.0050	0.0030	SW8081A	0.010	0.0040	0.0025	SW8081A	0.010	0.0030	0.0009
alpha-Chlordane	5103-71-9	µg/L	c	2.0		0.027	0.027	SW8081A	0.010	0.0050	0.0030	SW8081A	0.010	0.0040	0.0023	SW8081A	0.010	0.0030	0.0012
gamma-Chlordane	5103-74-2	µg/L	c	2.0		0.027	0.027	SW8081A	0.010	0.0030	0.0011	SW8081A	0.010	0.0040	0.0021	SW8081A	0.010	0.0030	0.0026
4,4-DDD	72-54-8	µg/L	c	NS		0.28	0.28	SW8081A	0.020	0.0050	0.0030	SW8081A	0.010	0.0040	0.0023	SW8081A	0.010	0.0030	0.0017
4,4-DDE	72-55-9	µg/L	c	NS		0.20	0.20	SW8081A	0.020	0.0030	0.0011	SW8081A	0.010	0.0040	0.0030	SW8081A	0.010	0.0030	0.0019
4,4-DDT	50-29-3	µg/L	c	NS		0.20	0.20	SW8081A	0.020	0.0050	0.0030	SW8081A	0.010	0.0040	0.0024	SW8081A	0.010	0.0030	0.0008
Dieldrin	60-57-1	µg/L	c	NS		0.0015	0.0015	SW8081A	0.020	0.0050	0.0030	SW8081A	0.010	0.0040	0.0021	SW8081A	0.010	0.0030	0.0012
Endosulfan I	959-98-8	µg/L	nc	NS		78	22	SW8081A	0.020	0.0050	0.0030	SW8081A	0.010	0.0040	0.0024	SW8081A	0.010	0.0030	0.0016
Endosulfan II	33213-65-9	µg/L	nc	NS		78	22	SW8081A	0.020	0.0050	0.0030	SW8081A	0.010	0.0040	0.0022	SW8081A	0.010	0.0030	0.0014
Endosulfan sulfate	1031-07-8	µg/L	nc	NS		78	22	SW8081A	0.020	0.0050	0.0030	SW8081A	0.010	0.0040	0.0025	SW8081A	0.010	0.0030	0.0026
Endrin	72-20-8	µg/L	nc	2.0		1.7	0.20	SW8081A	0.020	0.0050	0.0030	SW8081A	0.010	0.0040	0.0032	SW8081A	0.010	0.0030	0.0008
Endrin aldehyde	7421-93-4	µg/L	nc	NS	7.3	NS	NS	SW8081A	0.050	0.0030	0.0010	SW8081A	0.010	0.0050	0.0042	SW8081A	0.020	0.0060	0.0032
Endrin ketone	53494-70-5	µg/L	nc	NS	7.3	NS	NS	SW8081A	0.020	0.0050	0.0030	SW8081A	0.010	0.0040	0.0027	SW8081A	0.010	0.0030	0.0006
Heptachlor	76-44-8	µg/L	c	0.40		0.0018	0.0018	SW8081A	0.010	0.0050	0.0030	SW8081A	0.010	0.0040	0.0028	SW8081A	0.010	0.0030	0.0012
Heptachlor epoxide	1024-57-3	µg/L	c	0.20		0.0033	0.0033	SW8081A	0.010	0.0050	0.0030	SW8081A	0.010	0.0040	0.0035	SW8081A	0.010	0.0030	0.0010
Methoxychlor	72-43-5	µg/L	nc	40		27	4.0	SW8081A	0.10	0.0050	0.0030	SW8081A	0.010	0.0040	0.0020	SW8081A	0.010	0.0030	0.0011
Toxaphene	8001-35-2	µg/L	c	3.0		0.013	0.013	SW8081A	1.0	0.50	0.27	SW8081A	0.20	0.20	0.20	SW8081A	4.0	1.0	0.42
Polychlorinated Biphenyls (PCBs)																			
Aroclor 1016	12674-11-2	µg/L	c	NS		0.96	0.96	SW8082	0.50	0.10	0.045	SW8082	0.10	0.050	0.020	SW8082	not in current scope		
Aroclor 1221	11104-28-2	µg/L	c	NS		0.0043	0.0043	SW8082	0.50	0.13	0.062	SW8082	0.10	0.050	0.050	SW8082	not in current scope		
Aroclor 1232	11141-16-5	µg/L	c	NS		0.0043	0.0043	SW8082	0.50	0.10	0.041	SW8082	0.10	0.050	0.050	SW8082	not in current scope		
Aroclor 1242	53469-21-9	µg/L	c	NS		0.034	0.034	SW8082	0.50	0.10	0.041	SW8082	0.10	0.050	0.050	SW8082	not in current scope		
Aroclor 1248	12672-79-6	µg/L	c	NS		0.034	0.034	SW8082	0.50	0.080	0.071	SW8082	0.10	0.050	0.050	SW8082	not in current scope		
Aroclor 1254	11097-69-1	µg/L	c	NS		0.034	0.034	SW8082	0.50	0.13	0.044	SW8082	0.10	0.050	0.050	SW8082	not in current scope		
Aroclor 1260	11096-82-5	µg/L	c	NS		0.034	0.034	SW8082	0.50	0.10	0.039	SW8082	0.10	0.030	0.030	SW8082	not in current scope		
Total PCBs	1336-36-3	µg/L	c	0.50		0.17 (low risk)	0.050	SW8082	0.50	0.13	0.071	SW8082	0.10	0.050	0.050	SW8082	not in current scope		

TABLE A-1. REFERENCE LIMITS AND PROJECT ACTION LIMITS FOR GROUNDWATER
FALCON REFINERY SUPERFUND SITE

Analyte	CASRN	Units	c/nc	MCL[1]	TCEQ Residential $^{GW}GW_{Ing}$2	USEPA Tapwater RSL[3]	PAL[7]	Analytical Method	Achievable Laboratory Limits (TestAmerica, Tacoma)			Analytical Method	Achievable Laboratory Limits (Accutest)			Analytical Method	Achievable Laboratory Limits (BC Laboratories)		
									LOQ	LOD	DL		LOQ	LOD	DL		LOQ	LOD	DL
Total Metals *																			
Aluminum	7429-90-5	µg/L	-	NS		16,000	16,000	SW6010B	1,000	500	310	SW6020	50	40	13	SW6010B	50	39	39
Antimony	7440-36-0	µg/L	nc	6.0		6.0	0.60	SW6020	**2.0**	**1.0**	0.40	SW6020	**2.5**	**1.0**	0.43	SW6020	4.0	0.20	0.20
Arsenic	7440-38-2	µg/L	c	10		0.045	0.045	SW6020	**5.0**	**4.0**	**3.8**	SW6020	**1.0**	**0.50**	**0.36**	SW6020	**4.0**	**2.2**	**2.2**
Barium	7440-39-3	µg/L	nc	2,000		2,900	200	SW6020	6.0	0.50	0.27	SW6020	2.0	1.0	0.29	SW6020	2.0	0.23	0.23
Beryllium	7440-41-7	µg/L	c	4.0		16	0.40	SW6020	**2.0**	**1.0**	**0.51**	SW6020	**1.0**	**0.50**	0.061	SW6020	**2.0**	0.31	0.31
Cadmium	7440-43-9	µg/L	c	5.0		6.9	0.50	SW6020	**2.0**	0.30	0.14	SW6020	**1.0**	**0.60**	0.13	SW6020	**2.0**	0.20	0.20
Calcium**	7440-70-2	µg/L	-	NS	NS	NS	NS	SW6010B	1,100	150	100	SW6020	500	100	15	SW6010B	100	23	23
Chromium	7440-47-3	µg/L	nc	100		NS	10	SW6020	2.0	1.5	1.4	SW6020	6.0	5.0	0.11	SW6020	6.0	1.4	1.4
Cobalt	7440-48-4	µg/L	-	NS		4.7	4.7	SW6020	2.0	0.65	0.16	SW6020	1.0	0.50	0.11	SW6020	2.0	0.25	0.25
Copper	7440-50-8	µg/L	nc	1,300 (action		620	100	SW6020	5.0	1.0	0.55	SW6020	2.0	1.0	0.12	SW6020	4.0	0.65	0.65
Iron	7439-89-6	µg/L	-	NS		11,000	11,000	SW6010B	200	100	83	SW6020	50	25	7.8	SW6010B	50	6.7	6.7
Lead	7439-92-1	µg/L	c	15 (action		NS	15	SW6020	2.0	0.25	0.17	SW6020	1.0	0.50	0.027	SW6020	2.0	0.20	0.20
Magnesium**	7439-95-4	µg/L	-	NS	NS	NS	NS	SW6010B	1,100	300	230	SW6020	500	250	6.7	SW6010B	50	16	16
Manganese	7439-96-5	µg/L	-	NS		320	320	SW6020	2.0	1.5	0.95	SW6020	2.0	1.0	0.15	SW6020	2.0	1.1	1.1
Mercury	7439-97-6	µg/L	nc	2.0		0.63	0.20	SW7470A	0.20	0.10	0.041	SW7470A	0.20	0.020	0.020	SW7470A	0.20	0.030	0.03
Nickel	7440-02-0	µg/L	nc	NS		300	10	SW6020	**15**	2.5	2.0	SW6020	4.0	2.0	0.21	SW6020	4.0	0.33	0.33
Potassium**	7440-09-7	µg/L	-	NS	NS	NS	NS	SW6010B	3,300	500	410	SW6020	500	100	17	SW6010B	1,000	140	140
Selenium	7782-49-2	µg/L	nc	50		78	5.0	SW6020	5.0	4.0	3.6	SW6020	1.0	0.50	0.30	SW6020	4.0	0.34	0.34
Silver	7440-22-4	µg/L	nc	NS		71	10	SW6020	2.0	0.25	0.15	SW6020	1.0	0.50	0.053	SW6020	2.0	0.20	0.20
Sodium**	7440-23-5	µg/L	-	NS	NS	NS	NS	SW6010B	2,000	200	180	SW6020	500	100	9.3	SW6010B	500	77	77
Thallium	7440-28-0	µg/L	nc	2.0		0.16	0.16	SW6020	**5.0**	**2.5**	**1.4**	SW6020	**1.0**	**0.70**	0.079	SW6020	**2.0**	**0.20**	**0.20**
Vanadium	7440-62-2	µg/L	nc	NS		78	26	SW6020	10	5.0	4.9	SW6020	2.0	1.0	0.15	SW6020	6.0	2.2	2.2
Zinc	7440-66-6	µg/L	nc	NS		4,700	500	SW6020	7.0	5.0	4.4	SW6020	4.0	3.0	0.49	SW6020	10	5.9	5.9

Notes:

* Note that methods used for metals may vary by laboratory. The methods shown below are those used by TA Tacoma.

** These compounds are not necessarily of concern from a human health standpoint, therefore calculation of human health-based values is not required. However, aesthetics and ecological criteria would still apply. See table entitled "Compounds for which Calculation of a Human Health PCL is Not Required" available on the TCEQ website at http://www.tceq.state.tx.us/remediation/trrp/trrp.htm.

c - carcinogenic; nc - noncarcinogenic

TestAmerica analytes shown in bold and highlight have a PAL lower than or equal to the LOQ/LOD/DL.

Accutest analytes shown in bold and highlight have a PAL lower than or equal to the LOQ/LOD/DL.

BC Analytics analytes shown in bold and highlight have a PAL lower than or equal to the LOQ/LOD/DL.

[1] National Primary Drinking Water Regulations MCLs accessed at http://water.epa.gov/drink/contaminants/index.cfm#List in June 2012.

[2] TCEQ TRRP Table 3 Tier 1 Groundwater PCLs Residential, Commerical, and Industrial, June 29, 2012

[3] Regional Screening Levels (RSLs) (May 2012) as presented at USEPA website at http://www.epa.gov/region9/superfund/prg/

µg/L = microgram(s) per liter
CASRN = Chemical Abstracts Service Registry Number
DL = detection limit
NA = not applicable
NS = not specified
TCEQ = Texas Commission of Environmental Quality
TRRP = Texas Risk Reduction Program
USEPA = U.S. Environmental Protection Agency
VI = vapor intrusion

TABLE A-2. REFERENCE LIMITS AND PROJECT ACTION LIMITS FOR SURFACE WATER, FALCON REFINERY SUPERFUND SITE

Analyte	CASRN	c/nc	Units	TCEQ Surface Water Risk Based Exposure Limits (^{SW}RBEL)[1]						National Recommended Water Quality Criteria[2]					PAL[3]	Achievable Laboratory Limits (TestAmerica, Tacoma)			
				Aquatic Life Freshwater Acute	Aquatic Life Freshwater Chronic	Aquatic Life Saltwater Acute	Aquatic Life Saltwater Chronic	Human Health Water and Fish	Human Health Fish Only	Aquatic Life Freshwater Acute	Aquatic Life Freshwater Chronic	Aquatic Life Saltwater Acute	Aquatic Life Saltwater Chronic	Human Health for Consumption Organism Only		Analytical Method	LOQ	LOD	DL
Volatile Organic Compounds																			
Acetone	67-64-1	nc	µg/L	607,400	101,200	1,692,000	282,000	NS	NS	NS	NS	NS	NS	NS	101200	SW8260B	4.5	4.5	1.7
Benzene	71-43-2	c	µg/L	NS	130	NS	109	5	513	NS	NS	NS	NS	51	5	SW8260B	1.0	0.45	0.15
Bromobenzene	108-86-1	nc	µg/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	SW8260B	1.0	0.45	0.15
Bromochloromethane	74-97-5	nc	µg/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	SW8260B	1.0	0.70	0.24
Bromodichloromethane	75-27-4	c	µg/L	12,962	2,160	NS	NS	10.2	322	NS	NS	NS	NS	17	10	SW8260B	1.0	0.45	0.15
Bromoform	75-25-2	c	µg/L	897	149	7,320	1,220	69.1	2,175	NS	NS	NS	NS	140	69	SW8260B	1.0	0.45	0.15
Bromomethane (Methyl bromide)	74-83-9	nc	µg/L	660	110	3,600	600	47	1,500	NS	NS	NS	NS	1,500	47	SW8260B	5.0	2.3	0.75
2-Butanone (Methyl ethyl ketone)	78-93-3	nc	µg/L	254,420	42,400	NS	NS	13,932	1,500,000	NS	NS	NS	NS	NS	13932.0	SW8260B	10	4.5	1.5
n-Butylbenzene	104-51-8	nc	µg/L	213	36	NS	NS	NS	NS	NS	NS	NS	NS	NS	36	SW8260B	1.0	0.45	0.15
sec-Butylbenzene	135-98-8	nc	µg/L	246	41	NS	NS	NS	NS	NS	NS	NS	NS	NS	41	SW8260B	1.0	0.45	0.15
t-Butylbenzene	98-06-6	nc	µg/L	289	48	NS	NS	NS	NS	NS	NS	NS	NS	NS	48	SW8260B	1.0	0.45	0.15
Carbon disulfide	75-15-0	nc	µg/L	700	105	NS	NS	NS	NS	NS	NS	NS	NS	NS	105.00	SW8260B	1.0	0.45	0.15
Carbon tetrachloride	56-23-5	c	µg/L	NS	9.8	NS	1,500	4.1	29	NS	NS	NS	NS	1.6	1.6	SW8260B	1.0	0.45	0.15
Chlorobenzene	108-90-7	nc	µg/L	NS	64	NS	105	100	5,201	NS	NS	NS	NS	1,600	64.0	SW8260B	1.0	0.45	0.15
Chloroethane (Ethyl chloride)	75-00-3	nc	µg/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	SW8260B	5.0	2.3	0.75
Chloroform	67-66-3	c	µg/L	5,340	890	24,500	4,100	70	7,143	NS	NS	NS	NS	470	70.0	SW8260B	1.0	0.45	0.15
Chloromethane (Methyl chloride)	74-87-3	nc	µg/L	165,000	28,000	81,000	13,500	NS	NS	NS	NS	NS	NS	NS	13500.0	SW8260B	5.0	2.3	0.75
2-Chlorotoluene	95-49-8	nc	µg/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	SW8260B	1.0	0.45	0.15
4-Chlorotoluene	106-43-4	nc	µg/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	SW8260B	1.0	0.45	0.15
1,2-Dibromo-3-chloropropane (DBCP)	96-12-8	c	µg/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	SW8260B	2.0	1.5	0.52
Dibromochloromethane (Chlorodibromomethane)	124-48-1	c	µg/L	771	129	NS	NS	7.6	239	NS	NS	NS	NS	13	7.6	SW8260B	1.0	0.90	0.32
1,2-Dibromoethane (Ethylene dibromide [EDB])	106-93-4	c	µg/L	NS	NS	NS	NS	0.16	2.13	NS	NS	NS	NS	NS	NS	SW8260B	1.0	0.90	0.31
Dibromomethane (Methylene bromide)	74-95-3	nc	µg/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	SW8260B	1.0	0.45	0.15
1,2-Dichlorobenzene	95-50-1	nc	µg/L	660	110	591	99	600	4,336	NS	NS	NS	NS	1,300	99.00	SW8260B	1.0	0.45	0.15
1,3-Dichlorobenzene	541-73-1	nc	µg/L	153	85	855	142	473	1,445	NS	NS	NS	NS	960	85	SW8260B	1.0	0.45	0.15
1,4-Dichlorobenzene	106-46-7	c	µg/L	660	110	597	99	75	190	NS	NS	NS	NS	190	75.0	SW8260B	1.0	0.45	0.15
Dichlorodifluoromethane	75-71-8	nc	µg/L	11,780	1,963	NS	NS	NS	NS	NS	NS	NS	NS	NS	1,963	SW8260B	1.0	0.45	0.15
1,1-Dichloroethane	75-34-3	c	µg/L	15,370	2,570	NS	NS	NS	NS	NS	NS	NS	NS	NS	2570	SW8260B	1.0	0.45	0.15
1,2-Dichloroethane	107-06-2	c	µg/L	37,700	6,300	33,900	5,650	5	553	NS	NS	NS	NS	37	5	SW8260B	1.0	0.45	0.15
1,1-Dichloroethene	75-35-4	c	µg/L	9,100	1,500	75,000	12,500	7	23,916	NS	NS	NS	NS	7,100	7	SW8260B	1.0	0.45	0.15
1,2-Dichloroethene (cis)	156-59-2	nc	µg/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	SW8260B	1.0	0.45	0.15
1,2-Dichloroethene (trans)	156-60-5	nc	µg/L	66,000	22,000	NS	NS	100	10,000	NS	NS	NS	NS	10,000	100	SW8260B	1.0	0.45	0.15
1,2-Dichloropropane	78-87-5	c	µg/L	11,200	1,870	NS	2,400	5	226	NS	NS	NS	NS	15	5	SW8260B	1.0	0.45	0.15
1,3-Dichloropropane	142-28-9	nc	µg/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	SW8260B	1.0	0.45	0.15
2,2-Dichloropropane	594-20-7	-	µg/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	SW8260B	1.0	0.45	0.15
1,1-Dichloropropene	563-58-6	-	µg/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	SW8260B	1.0	0.45	0.15
1,3-Dichloropropene (cis)	10061-01-5	-	µg/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	SW8260B	1.0	0.45	0.15
1,3-Dichloropropene (trans)	10061-02-6	-	µg/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	SW8260B	1.0	0.45	0.15
1,3-Dichloropropene (total)	542-75-6	c	µg/L	1,230	205	237	40	3.4	211	NS	NS	NS	NS	21	3.400	SW8260B	2.0	0.90	0.30
Ethylbenzene	100-41-4	c	µg/L	6,540	1,090	1,494	249	700	7,143	NS	NS	NS	NS	2,100	249.0	SW8260B	1.0	0.45	0.15
Hexachlorobutadiene	87-68-3	c	µg/L	NS	0.93	NS	0.32	6.5	274	NS	NS	NS	NS	18	0.320	SW8260B	1.0	0.45	0.15
2-Hexanone	591-78-6	nc	µg/L	36,790	6,130	NS	NS	NS	NS	NS	NS	NS	NS	NS	6130	SW8260B	5.0	2.3	0.75
Isopropylbenzene (Cumene)	98-82-8	nc	µg/L	1,530	255	NS	NS	NS	NS	NS	NS	NS	NS	NS	255.0	SW8260B	1.0	0.45	0.15
p-Isopropyltoluene	99-87-6	-	µg/L	254	42	NS	NS	NS	NS	NS	NS	NS	NS	NS	42	SW8260B	1.0	0.45	0.15
4-Methyl-2-pentanone (Methyl isobutyl ketone [MIBK])	108-10-1	nc	µg/L	158,100	26,400	369,000	61,500	NS	NS	NS	NS	NS	NS	NS	26400	SW8260B	5.0	2.3	0.75
Methylene chloride	75-09-2	c	µg/L	66,000	11,000	32,500	5,420	5	5,926	NS	NS	NS	NS	590	5	SW8260B	3.0	0.45	0.15
Methyl-tertiary-butyl ether (MtBE)	1634-04-4	c	µg/L	66,043	11,000	NS	NS	NS	NS	NS	NS	NS	NS	NS	11,000	SW8260B	1.0	0.45	0.15
Naphthalene	91-20-3	nc	µg/L	1,480	250	750	125	NS	NS	NS	NS	NS	NS	NS	125.0	SW8260B	1.0	0.45	0.15
n-Propylbenzene	103-65-1	nc	µg/L	385	64	NS	NS	NS	NS	NS	NS	NS	NS	NS	64	SW8260B	1.0	0.45	0.15
Styrene	100-42-5	nc	µg/L	7,515	1,250	2,730	455	NS	NS	NS	NS	NS	NS	NS	455	SW8260B	1.0	0.45	0.15
1,1,1,2-Tetrachloroethane	630-20-6	c	µg/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	SW8260B	1.0	0.45	0.15
1,1,2,2-Tetrachloroethane	79-34-5	c	µg/L	2,790	465	2,706	451	3.2	76	NS	NS	NS	NS	4.0	3.2	SW8260B	1.0	0.45	0.15
Tetrachloroethene (PCE)	127-18-4	c	µg/L	4,700	790	8,700	1,450	5	49	NS	NS	NS	NS	3.3	3.3	SW8260B	1.0	0.45	0.15
Toluene	108-88-3	nc	µg/L	8,700	1,450	2,850	480	1000	15,000	NS	NS	NS	NS	15,000	480.0	SW8260B	1.0	0.45	0.15
1,2,3-Trichlorobenzene	87-61-6	nc	µg/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.0	SW8260B	1.0	0.45	0.15
1,2,4-Trichlorobenzene	120-82-1	nc	µg/L	309	51.5	135	22.5	35	70	NS	NS	NS	NS	70	23	SW8260B	1.0	0.45	0.15
1,1,1-Trichloroethane	71-55-6	nc	µg/L	14,700	2,450	9,400	1,560	200	956,663	NS	NS	NS	NS	NS	200	SW8260B	1.0	0.45	0.15
1,1,2-Trichloroethane	79-00-5	c	µg/L	5,400	900	1,650	275	5	295	NS	NS	NS	NS	16	5	SW8260B	1.0	0.45	0.15
Trichloroethene (TCE)	79-01-6	nc	µg/L	[13] 3,331	[11] 555	[10] 5,800	[10] 970	5	649	NS	NS	NS	NS	30	5	SW8260B	1.0	0.45	0.15
Trichlorofluoromethane	75-69-4	nc	µg/L	5,225	871	NS	NS	NS	NS	NS	NS	NS	NS	NS	871	SW8260B	1.0	0.45	0.15
1,2,3-Trichloropropane	96-18-4	c	µg/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	SW8260B	1.0	0.45	0.15
1,2,4-Trimethylbenzene	95-63-6	nc	µg/L	462	77	1,305	217	NS	NS	NS	NS	NS	NS	NS	77	SW8260B	1.0	0.45	0.15
1,3,5-Trimethylbenzene	108-67-8	nc	µg/L	424.5	71	NS	NS	NS	NS	NS	NS	NS	NS	NS	71	SW8260B	1.0	0.45	0.15
Vinyl chloride	75-01-4	c	µg/L	16,900	2,820	NS	NS	0.25	24	NS	NS	NS	NS	2.4	0.3	SW8260B	1.0	0.45	0.15
Xylenes (total)	1330-20-7	nc	µg/L	4,020	1,340	2,500	850	NS	NS	NS	NS	NS	NS	NS	850	SW8260B	3.0	1.4	0.45
Semivolatile Organic Compounds																			
Benzoic acid	65-85-0	nc	µg/L	54,000	9,000	NS	NS	NS	NS	NS	NS	NS	NS	NS	9000	SW8270C	10	5.0	3.0
Benzyl alcohol	100-51-6	-	µg/L	NS	8.6	NS	NS	NS	NS	NS	NS	NS	NS	NS	8.6	SW8270C	2.0	1.0	0.50
Bis(2-chloroethoxy)methane	111-91-1	-	µg/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	SW8270C	2.0	1.0	0.50
Bis(2-chloroethyl)ether	111-44-4	c	µg/L	72,000	12,000	NS	NS	0.3	5.27	NS	NS	NS	NS	NS	0	SW8270C	2.0	1.0	0.50
Bis(2-chloroisopropyl) ether	108-60-1	c	µg/L	37,847	6,308	NS	NS	1,400	65,000	NS	NS	NS	NS	170,000	1,400	SW8270C	2.0	1.0	0.50
Bis(2-ethylhexyl) phthalate	117-81-7	c	µg/L	NS	300	NS	NS	6	41	NS	NS	NS	NS	NS	6.00	SW8270C	15	10	5.9
4-Bromophenyl phenyl ether	101-55-3	-	µg/L	NS	1.5	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.5	SW8270C	2.0	1.0	0.50
Butyl benzyl phthalate	85-68-7	c	µg/L	560	93	883	147	1,500	1,900	NS	NS	NS	NS	5,200	93	SW8270C	3.0	1.0	1.0
Carbazole	86-74-8	c	µg/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	SW8270C	2.0	1.0	0.50
4-Chloro-3-methylphenol	59-50-7	nc	µg/L	NS	0.3	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	SW8270C	2.0	1.0	0.50
4-Chloroaniline	106-47-8	c	µg/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0	SW8270C	2.0	1.0	0.50
2-Chloronaphthalene	91-58-7	nc	µg/L	323	54	NS	NS	1,000	1,600	NS	NS	NS	NS	4,300	54.00	SW8270C	0.30	0.15	0.10
2-Chlorophenol	95-57-8	nc	µg/L	780	130	1,590	265	81	150	NS	NS	NS	NS	400	81	SW8270C	2.0	1.0	0.50
4-Chlorophenyl phenyl ether	7005-72-3	-	µg/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	SW8270C	2.0	1.0	0.50
Dibenzofuran	132-64-9	nc	µg/L	562	94	393	65	NS	NS	NS	NS	NS	NS	NS	65.0	SW8270C	2.0	1.0	0.50
3,3-Dichlorobenzidine	91-94-1	c	µg/L	315	53	219	37	0.32	0.44	NS	NS	NS	NS	NS	0.3	SW8270C	10	1.0	0.50
2,4-Dichlorophenol	120-83-2	nc	µg/L	510	85	NS	NS	77	290	NS	NS	NS	NS	NS	77	SW8270C	2.0	1.0	0.50
Diethyl phthalate	84-66-2	nc	µg/L	6,259	1,043	2,653	442	17,000	44,000	NS	NS	NS	NS	120,000	442	SW8270C	2.0	1.0	0.50
2,4-Dimethylphenol	105-67-9	nc	µg/L	630	105	NS	NS	257	571	NS	NS	NS	NS	2,300	105	SW8270C	10	2.0	1.5
4,6-Dinitro-2-methylphenol	534-52-1	-	µg/L	69	12	NS	NS	13	280	NS	NS	NS	NS	765	12.0	SW8270C	20	10	5.0
2,4-Dinitrophenol	51-28-5	nc	µg/L	186	31	3,990	670	69	5,300	NS	NS	NS	NS	14,000	31.0	SW8270C	25	10	5.0
2,4-Dinitrotoluene	121-14-2	nc	µg/L	7,290	1,220	NS	NS	1.1	34	NS	NS	NS	NS	NS	1	SW8270C	2.0	1.0	0.50
2,6-Dinitrotoluene	606-20-2	c	µg/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0	SW8270C	2.0	1.0	0.50
Dimethyl phthalate	131-11-3	nc	µg/L	NS	330	NS	580	270,000	1,100,000	NS	NS	NS	NS	2,900,000	330.0	SW8270C	2.0	1.0	0.50
Di-n-butyl phthalate	84-74-2	nc	µg/L	221	7	150	5	1,318	3,010	NS	NS	NS	NS	12,000	5.0	SW8270C	2.0	1.0	0.65
Di-n-octyl phthalate	117-84-0	nc	µg/L	671	22	NS	NS	NS	NS	NS	NS	NS	NS	NS	22	SW8270C	2.0	1.0	1.0
Hexachlorobenzene	118-74-1	c	µg/L	NS	NS	NS	NS	0.0044	0.0045	NS	NS	NS	NS	NS	0.00440	SW8270C	2.0	1.0	0.50
Hexachlorocyclopentadiene	77-47-4	nc	µg/L	2.1	0.07	NS	0.07	50	1,100	NS	NS	NS	NS	17,000	0.070	SW8270C	10	1.0	0.50
Hexachloroethane	67-72-1	c	µg/L	NS	12	NS	9.4	27	62	NS	NS	NS	NS	NS	9.4	SW8270C	3.0	1.0	0.50
Isophorone	78-59-1	c	µg/L	36,000	6,000	3,870	650	350	9,600	NS	NS	NS	NS	NS	350	SW8270C	2.0	1.0	0.50
2-Methylphenol	95-48-7	c	µg/L	3,360	560	3,060	510	NS	NS	NS	NS	NS	NS	NS	510	SW8270C	2.0	1.0	0.50
3- & 4-Methylphenols	15831-10-4	c	µg/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	SW8270C	4.0	1.0	0.50
2-Nitroaniline	88-74-4	nc	µg/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	SW8270C	2.0	1.0	0.50
3-Nitroaniline	99-09-2	-	µg/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	SW8270C	2.0	1.0	0.60
4-Nitroaniline	100-01-6	c	µg/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	SW8270C	3.0	1.0	0.50
Nitrobenzene	98-95-3	c	µg/L	NS	270	NS	66.8	11	463	NS	NS	NS	NS	1,900	11	SW8270C	2.0	1.0	0.50
2-Nitrophenol	88-75-5	-	µg/L	5,753	959	8,818	1,470	NS	NS	NS	NS	NS	NS	NS	959	SW8270C	2.0	1.0	0.50
4-Nitrophenol	100-02-7	-	µg/L	3,193	532	2,151	359	NS	NS	NS	NS	NS	NS	NS	359	SW8270C	10	10	5.0
N-Nitrosodimethylamine	62-75-9	c	µg/L	282,000	47,000	990,000	165,000	0.0069	30	NS	NS	NS	NS	NS	0	SW8270C	10	2.5	1.0
N-Nitrosodi-n-propylamine	621-64-7	c	µg/L	600	20	3,600	120	0.05	5.1	NS	NS	NS	NS	NS	0	SW8270C	2.0	1.0	0.50
N-Nitrosodiphenylamine	86-30-6	c	µg/L	1,740	290	990,000	165,000	33	60	NS	NS	NS	NS	NS	33	SW8270C	2.0	1.0	0.50
Pentachlorophenol	87-86-5	c	µg/L	[12] 3.19	[12] 2.45	15.1	9.6	1	57	19 [6]	15 [6]	13	7.9	NS	1.00	SW8270C	3.5	1.0	0.50
Phenol	108-95-2	nc	µg/L	NS	110	16,500	2,750	10,000	860,000	NS	NS	NS	NS	4,600,000	110.0	SW8270C	3.0	1.0	0.50
1,2,4-Trichlorobenzene	120-82-1	nc	µg/L	309	51.5	135	22.5	35	70	NS	NS	NS	NS	940	23	SW8270C	2.0	1.0	0.50
2,4,5-Trichlorophenol	95-95-4	nc	µg/L	136	64	259	12	1,194	2,435	NS	NS	NS	NS	NS	12	SW8270C	2.0	1.0	0.50
2,4,6-Trichlorophenol	88-06-2	c	µg/L	81	13.5	363	61	14	24	NS	NS	NS	NS	NS	13.5	SW8270C	3.0	1.0	0.50
Polycyclic Aromatic Hydrocarbons																			
Acenaphthene	83-32-9	nc	µg/L	NS	23	NS	40.4	670	990	NS	NS	NS	NS	990	23.0	SW8270C SIM	0.10	0.075	0.030
Acenaphthylene	208-96-8	nc	µg/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0	SW8270C SIM	0.10	0.075	0.030
Anthracene	120-12-7	nc	µg/L	1.8	0.3	1.08	0.18	5,569	40,000	NS	NS	NS	NS	40,000	0.180	SW8270C SIM	0.10	0.075	0.030
Benzo(a)anthracene	56-55-3	c	µg/L	207.6	34.6	NS	NS	0.068	0.33	NS	NS	NS	NS	0.018	0.018	SW8270C SIM	0.10	0.075	0.030
Benzo(a)pyrene	50-32-8	c	µg/L	NS	0.014	NS	NS	0.068	0.33	NS	NS	NS	NS	0.018	0.014	SW8270C SIM	0.20	0.075	0.030
Benzo(b)fluoranthene	205-99-2	c	µg/L	NS	NS	NS	NS	0.038	0.18	NS	NS	NS	NS	0.018	0.018	SW8270C SIM	0.10	0.075	0.030
Benzo(g,h,i)perylene	191-24-2	nc	µg/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.0	SW8270C SIM	0.10	0.075	0.030
Benzo(k)fluoranthene	207-08-9	c	µg/L	NS	NS	NS	NS	0.038	0.18	NS	NS	NS	NS	0.018	0.018	SW8270C SIM	0.10	0.075	0.030
Chrysene	218-01-9	c	µg/L	207	7	NS	NS	68.13	327	NS	NS	NS	NS	0.018	0.018	SW8270C SIM	0.10	0.075	0.030
Dibenz(a,h)anthracene	53-70-3	c	µg/L	149	5	NS	NS	0.038	0.18	NS	NS	NS	NS	0.018	0.018	SW8270C SIM	0.10	0.075	0.030
Fluoranthene	206-44-0	nc	µg/L	NS	6.16	NS	2.96	130	140	NS	NS	NS	NS	140	2.960	SW8270C SIM	0.10	0.075	0.030
Fluorene	86-73-7	nc	µg/L	64	11	300	50	1,100	5,300	NS	NS	NS	NS	5,300	11.0	SW8270C SIM	0.10	0.075	0.030
Indeno(1,2,3-cd)pyrene	193-39-5	c	µg/L	NS	NS	NS	NS	0.038	0.18	NS	NS	NS	NS	0.018	0.018	SW8270C SIM	0.10	0.075	0.030
1-Methylnaphthalene	90-12-0	c	µg/L	NS	2.1	NS	NS	NS	NS	NS	NS	NS	NS	NS	2.1	SW8270C SIM	0.10	0.075	0.030
2-Methylnaphthalene	91-57-6	nc	µg/L	380	63	180	30	NS	NS	NS	NS	NS	NS	NS	30.0	SW8270C SIM	0.13	0.075	0.030
Naphthalene	91-20-3	nc	µg/L	1,480	250	750	125	NS	NS	NS	NS	NS	NS	NS	125.0	SW8270C SIM	0.10	0.075	0.036
Phenanthrene	85-01-8	nc	µg/L	30	30	7.7	4.6	NS	NS	NS	NS	NS	NS	NS	4.60	SW8270C SIM	0.10	0.075	0.030
Pyrene	129-00-0	nc	µg/L	206	7	7.4	0.24	830	4,000	NS	NS	NS	NS	4,000	0.240	SW8270C SIM	0.10	0.075	0.030
Organochlorine Pesticides																			
Aldrin	309-00-2	c	µg/L	3	[14] 0.3	1.3	[14] 0.13	0.00094	0.001	3.0	NS	1.3	NS	0.00005	0.00005	SW8081A	0.010	0.0050	0.0030
alpha-BHC	319-84-6	c	µg/L	447	74	150	25	0.05	0.093	NS	NS	NS	NS	0.0049	0.0049	SW8081A	0.010	0.0050	0.0030
beta-BHC	319-85-7	c	µg/L	498	83	NS	NS	0.17	0.33	NS	NS	NS	NS	0.017	0.017	SW8081A	0.020	0.0050	0.0030
delta-BHC	319-86-8	c	µg/L	249	141	NS	NS	NS	NS	NS	NS	NS	NS	NS	141.0	SW8081A	0.010	0.0050	0.0030
gamma-BHC (Lindane)	58-89-9	c	µg/L	1.126	0.08	0.16	[14] 0.016	0.2	6.2	0.95	NS	0.16	NS	1.8	0.08	SW8081A	0.020	0.0050	0.0030
alpha-Chlordane	5103-71-9	c	µg/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	SW8081A	0.010	0.0050	0.0030
gamma-Chlordane	5103-74-2	c	µg/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	SW8081A	0.010	0.0050	0.0030
Chlordane (total)	12789-03-6	c	µg/L	2.4	0.004	0.09	0.004	0.008	0.00810	2.4	0.0043	0.09	0.004	0.00081	0.00081	SW8081A	0.010	0.0050	0.0030
4,4-DDD	72-54-8	c	µg/L	NS	0.011	NS	0.025	0.0031	0.0031	1.1	0.0010	NS	NS	0.00031	0.00031	SW8081A	0.020	0.0050	0.0030
4,4-DDE	72-55-9	c	µg/L	NS	10.5	NS	0.14	0.004	0.004	1.1	0.0010	NS	NS	0.00022	0.0002200000	SW8081A	0.020	0.0050	0.0030
4,4-DDT	50-29-3	c	µg/L	1.1	0.001	0.13	0.001	0.0039	0.0039	1.1	0.0010	0.13	0.001	0.00022	0.000220	SW8081A	0.020	0.0050	0.0030
Dieldrin	60-57-1	c	µg/L	0.24	0.002	0.71	0.002	0.0005	0.0005	0.24	0.056	0.71	0.0019	0.000054	0.000054	SW8081A	0.010	0.0050	0.0030
Endosulfan I	959-98-8	nc	µg/L	0.22	0.056	0.034	0.009	62	89	0.22	0.056	0.034	0.0087	89	0.009	SW8081A	0.020	0.0050	0.0030
Endosulfan II	33213-65-9	nc	µg/L	0.22	0.056	0.034	0.009	62	89	0.22	0.056	0.034	0.0087	89	0.009	SW8081A	0.020	0.0050	0.0030
Endosulfan sulfate	1031-07-8	nc	µg/L	0.22	0.056	0.034	0.009	62	89	NS	NS	NS	NS	89	0.009	SW8081A	0.020	0.0050	0.0030
Endosulfan (total)	115-29-7	nc	µg/L	NS	0.051	NS	NS	NS	NS	0.22	0.056	NS	NS	89	0.0510	SW8081A	0.020	0.0050	0.0030
Endrin	72-20-8	nc	µg/L	0.086	0.002	0.037	0.002	0.2	0.2	0.086	0.036	0.037	0.0023	0.060	0.0020	SW8081A	0.020	0.0050	0.0030
Endrin aldehyde	7421-93-4	nc	µg/L	36,300	1,210	NS	NS	0.29	0.3	NS	NS	NS	NS	0.30	0.29	SW8081A	0.050	0.0050	0.0030
Endrin ketone	53494-70-5	nc	µg/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	SW8081A	0.020	0.0050	0.0030
Heptachlor	76-44-8	c	µg/L	0.52	0.004	0.053	0.004	0.0015	0.0015	0.52	0.0038	0.053	0.0036	0.000079	0.000079	SW8081A	0.010	0.0050	0.0030
Heptachlor epoxide	1024-57-3	c	µg/L	0.52	0.0038	0.053	0.0036	0.00074	0.00075	0.52	0.0038	0.053	0.0036	0.000039	0.000039	SW8081A	0.010	0.0050	0.0030
Methoxychlor	72-43-5	nc	µg/L	NS	0.03	NS	0.03	0.33	0.33	NS	0.030	NS	0.030	NS	0.030	SW8081A	0.10	0.0050	0.0030
Toxaphene	8001-35-2	c	µg/L	0.78	0.0002	0.21	0.0002	0.0053	0.0053	0.73	0.00020	0.21	0.0002	0.00028	0.00020	SW8081A	1.0	0.50	0.30

TABLE A-2. REFERENCE LIMITS AND PROJECT ACTION LIMITS FOR SURFACE WATER,
FALCON REFINERY SUPERFUND SITE

Analyte	CASRN	c/nc	Units	TCEQ Surface Water Risk Based Exposure Limits (^{SW}RBEL)[1]						National Recommended Water Quality Criteria[2]					PAL[3]	Achievable Laboratory Limits (TestAmerica, Tacoma)			
				Aquatic Life Freshwater Acute	Aquatic Life Freshwater Chronic	Aquatic Life Saltwater Acute	Aquatic Life Saltwater Chronic	Human Health Water and Fish	Human Health Fish Only	Aquatic Life Freshwater Acute	Aquatic Life Freshwater Chronic	Aquatic Life Saltwater Acute	Aquatic Life Saltwater Chronic	Human Health for Consumption Organism Only		Analytical Method	LOQ	LOD	DL
Metals																			
Aluminum	7429-90-5	-	µg/L	991w (d)	[9] 87	NS	NS	NS	NS	NS	NS	NS	NS	NS	0	SW6010B	**1,000**	**930**	**310**
Antimony	7440-36-0	nc	µg/L	NS	160	NS	NS	6	1,071	NS	NS	NS	NS	NS	6	SW6020	2.0	1.0	0.40
Arsenic	7440-38-2	c	µg/L	340w	150w	149w	78w	10	10	340	150	69	36	NS	10.0	SW6020	5.0	3.8	3.8
Barium	7440-39-3	nc	µg/L	NS	16,000	NS	25,000	2,000	NS	NS	NS	NS	NS	NS	2000.0	SW6020	**6.0**	0.50	0.27
Beryllium	7440-41-7	c	µg/L	130	5.3	NS	NS	NS	NS	NS	NS	NS	NS	NS	5.30	SW6020	**2.0**	**1.0**	0.51
Cadmium	7440-43-9	c	µg/L	[8] 4.37	[8] 0.15	40.0w	8.75w	5	NS	2.0 [4]	0.25 [4]	40	8.8	NS	5.000	SW6020	**2.0**	**0.30**	**0.14**
Calcium	7440-70-2	-	µg/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0	SW6010B	1,100	85	28
Total Chromium	7440-47-3	-	µg/L	NS	NS	NS	NS	NS	NS	16 [5]	11 [5]	NS	NS	NS	0.0	SW6020	2.0	1.5	1.4
Chromium (Tri)(d)	16065-83-1	nc	µg/L	[8] 323	[8] 42.0	NS	[11] 103	NS	NS	NS	NS	NS	NS	NS	NS	--	--	--	--
Chromium (Hex)(d)	18540-29-9	c	µg/L	15.7w	10.6w	1,090w	49.6w	62	502	NS	NS	1,100	50	NS	NS	--	--	--	--
Cobalt	7440-48-4	-	µg/L	45,000	1,500	NS	NS	NS	NS	NS	NS	NS	NS	NS	1500.0	SW6020	2.0	0.30	0.16
Copper	7440-50-8	nc	µg/L	[8] 7.39	[8] 5.24	[7] 13.5w	3.6w	1,300	NS	13 [4]	9.0 [4]	4.8	3.1	NS	3.100	SW6020	**5.0**	**1.0**	**0.55**
Iron	7439-89-6	-	µg/L	NS	1,000	NS	NS	300	NS	NS	1,000	NS	NS	NS	300	SW6010B	**200**	**94**	**32**
Lead	7439-92-1	c	µg/L	[8] 30.14	[8] 1.17	133w	5.3w	1.15	3.83	65 [4]	2.5 [4]	210	8.1	NS	1.15	SW6020	**2.0**	0.35	0.17
Magnesium	7439-95-4	-	µg/L	19,410	3,235	NS	NS	NS	NS	NS	NS	NS	NS	NS	3235	SW6010B	**1,100**	**700**	230
Manganese	7439-96-5	-	µg/L	NS	120	NS	NS	50	100	NS	NS	NS	NS	NS	50	SW6020	2.0	2.0	0.95
Mercury	7439-97-6	nc	µg/L	2.4	1.3	2.1	1.1	0.021	0.021	1.4	0.77	1.8	0.94	NS	0.0210	SW7470A	**0.20**	**0.10**	**0.041**
Nickel	7440-02-0	nc	µg/L	[8] 260.5	[8] 28.93	118w	13.1w	332	1,140	470 [4]	52 [4]	74	8.2	NS	8.2	SW6020	**15**	2.0	2.0
Potassium	7440-09-7	-	µg/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0	SW6010B	3,300	1,200	410
Selenium	7782-49-2	nc	µg/L	20	5	564	136	50	4200	NS	4.6	290	71	NS	4.6	SW6020	**5.0**	**3.6**	**3.6**
Silver	7440-22-4	nc	µg/L	0.8w	[14] 0.08w	2w	[14] 0.2w	NS	NS	3.2 [4]	NS	1.9	NS	NS	1.900	SW6020	**2.0**	**0.25**	**0.15**
Sodium	7440-23-5	-	µg/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0	SW6010B	2,000	550	180
Thallium	7440-28-0	nc	µg/L	NS	4	NS	21.3	0.75	1.5	NS	NS	NS	NS	NS	0.75	SW6020	**5.0**	**3.0**	**1.4**
Vanadium	7440-62-2	nc	µg/L	NS	20	NS	NS	NS	NS	NS	NS	NS	NS	NS	20	SW6020	10	10	4.9
Zinc	7440-66-6	nc	µg/L	[8] 65.13	[8] 65.66	92.7w	84.2w	7,400	26,000	120 [4]	120 [4]	90	81	NS	81	SW6020	7.0	5.0	4.4

Notes:

TestAmerica analytes shown in bold and highlight have a PAL lower than or equal to the LOQ/LOD/DL.

[1] TCEQ TRRP Human Health Surface Water RBELs Table and Aquatic Life Surface Water RBELs Table, updated January 2011 http://www.tceq.state.tx.us/remediation/trrp/trrppcls.html

[2] USEPA National Water Quality Criteria (accessed 18 June 2012 at http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm).

[3] PALs refer to EPA - National Recommended Water Quality Criteria, if not available then TCEQ RBEL

[4] Based on a dissolved metal, at a hardness of 100 mg/L as calcium carbonate.

[5] Criteria for hexavalent chromium, based on a dissolved metal, at a hardness of 100 mg/L as calcium carbonate.

[6] Based on a pH of 7.8.

[7] In designated oyster waters, an acute saltwater copper criterion of 3.6 ug/L applies.

[8] Value calculated using an assumed hardness of 50 mg/L as $CaCO_3$. The hardness-based formulas are on the next sheet. Persons should use the lower fifteenth percentile hardness value for the nearest downstream classified segment as listed in the agency's Implementation Procedures, as amended. Alternatively, site-specific hardness values may be used. See discussion in Section 3.2.3 of of TRRP-24.

[9] National Recommended Water Quality Criterion as provided in U.S. EPA, 2009.

[10] Value derived by TCEQ using the LC_{50} approach.

[11] Chronic value is a surface water benchmark from the TCEQ Ecological Risk Assessment Guidance (RG-263 and updates).

[12] Value calculated using an assumed pH of 6. See formula on the next sheet and discussion in Section 3.2.3 of TRRP-24 for guidance on the appropriate pH value to use.

[13] Acute value derived by the TCEQ Water Quality Division, 2003. In-house water quality chronic and acute values derived for wastewater permits and requests from the Office of Waste based on LC50 values in accordance with methodology defined in the TSWQS.

[14] The indicated chronic value is an acute criterion (state or federal) divided by 10.

(d) Indicates that the criteria for a specific parameter are for the dissolved portion in water. All other criteria are for total concentrations, except where noted.recoverable

(w) Indicates that a criterion is multiplied by a water-effect ratio (WER) in order to incorporate the effects of local water chemistry or toxicity. The WER is equal to 1 except where sufficient data is available to establish a site-specific WER. The number preceding the w in the freshwater criterion equation is an EPA conversion factor.

µg/L = microgram(s) per liter
mg/L = milligram(s) per liter
CASRN = Chemical Abstracts Service Registry Number
DL = detection limit
LOD = limit of detection
RBEL = Risk Based Exposure Limits
TCEQ = Texas Commission on Environmental Quality
TRRP = Texas Risk Reduction Program

TABLE A-3. REFERENCE LIMITS AND PROJECT ACTION LIMITS FOR SURFACE AND SUBSURFACE SOIL, FALCON REFINERY SUPERFUND SITE

Analyte	CASRN	Units	c/nc	TCEQ TRRP Residential Levels[1]			USEPA Regional Screening Levels [5]					PAL [10]	Achievable Laboratory Limits (TestAmerica,		
				$^{Tot}Soil_{Comb}$	$^{GW}Soil_{Ing}$	$^{Air}Soil_{Inh-V}$	Residential	Industrial	Protection of Ground Water	USEPA Eco-SSL Lowest Value [8]	USEPA Eco-SSL Additional Values [8]		LOQ	LOD	DL
Volatile Organic Compounds															
Acetone	67-64-1	µg/kg	nc	66,000,000	43,000	650,000,000	61,000,000	630,000,000	2,400	NP	NP	2,400	400	300	100
Benzene	71-43-2	µg/kg	c	120,000	26	160,000	1,100	5,400	0.20	NP	NP	0.20	16	10	4.0
Bromobenzene	108-86-1	µg/kg	nc	390,000	230	970,000	300,000	1,800,000	36	NP	NP	36	40	30	10
Bromochloromethane	74-97-5	µg/kg	nc				160,000	680,000	21	NP	NP	21	40	30	12
Bromodichloromethane	75-27-4	µg/kg	c	98,000	65	NP	270	1,400	0.032	NP	NP	0.032	40	30	10
Bromoform	75-25-2	µg/kg	c	400,000	630	840,000	62,000	220,000	2.1	NP	NP	2.1	40	30	11
Bromomethane (Methyl bromide)	74-83-9	µg/kg	nc	46,000	130	77,000	7,300	32,000	1.8	NP	NP	1.8	140	100	35
2-Butanone (Methyl ethyl ketone)	78-93-3	µg/kg	nc	4,000,000	29,000	200,000,000	28,000,000	200,000,000	1,000	NP	NP	1,000	400	300	100
n-Butylbenzene	104-51-8	µg/kg	nc	3,300,000	150,000	NP	3,900,000	51,000,000	2,500	NP	NP	2,500	40	30	10
sec-Butylbenzene	135-98-8	µg/kg	nc	3,300,000	85,000	NP	NS	NS	NS	NP	NP	85,000	40	30	10
t-Butylbenzene	98-06-6	µg/kg	nc	3,300,000	100,000	NP	NS	NS	NS	NP	NP	100,000	40	30	10
Carbon disulfide	75-15-0	µg/kg	nc				820,000	3,700,000	210	NP	NP	210	40	30	10
Carbon tetrachloride	56-23-5	µg/kg	c				610	3,000	0.15	NP	NP	0.15	20	15	5.0
Chlorobenzene	108-90-7	µg/kg	nc				290,000	1,400,000	49	NP	NP	49	40	30	10
Chloroethane (Ethyl chloride)	75-00-3	µg/kg	c				15,000,000	61,000,000	5,900	NP	NP	5,900	400	300	100
Chloroform	67-66-3	µg/kg	c				290	1,500	0.053	NP	NP	0.053	40	30	10
Chloromethane (Methyl chloride)	74-87-3	µg/kg	c				120,000	500,000	49	NP	NP	49	400	300	100
2-Chlorotoluene	95-49-8	µg/kg	nc				1,600,000	20,000,000	170	NP	NP	170	40	30	10
4-Chlorotoluene	106-43-4	µg/kg	nc				1,600,000	20,000,000	180	NP	NP	180	40	30	13
1,2-Dibromo-3-chloropropane (DBCP)	96-12-8	µg/kg	c				5.4	69	0.00014	NP	NP	0.00014	200	150	66
Dibromochloromethane (Chlorodibromomethane)	124-48-1	µg/kg	c				680	3,300	0.039	NP	NP	0.039	40	30	10
1,2-Dibromoethane (Ethylene dibromide [EDB])	106-93-4	µg/kg	c				34	170	0.0018	NP	NP	0.0018	40	30	10
Dibromomethane (Methylene bromide)	74-95-3	µg/kg	nc				25,000	110,000	1.9	NP	NP	1.9	40	30	10
1,2-Dichlorobenzene	95-50-1	µg/kg	nc	720,000			1,900,000	9,800,000	270	NP	NP	270	40	30	10
1,3-Dichlorobenzene	541-73-1	µg/kg	nc	120,000	6,700	120,000	NS	NS	NS	NP	NP	6,700	40	30	10
1,4-Dichlorobenzene	106-46-7	µg/kg	c	250,000			2,400	12,000	0.40	NP	NP	0.40	40	30	10
Dichlorodifluoromethane	75-71-8	µg/kg	nc				94,000	400,000	300	NP	NP	300	40	30	10
1,1-Dichloroethane	75-34-3	µg/kg	c				3,300	17,000	0.68	NP	NP	0.68	40	30	10
1,2-Dichloroethane	107-06-2	µg/kg	c				430	2,200	0.042	NP	NP	0.042	40	30	10
1,1-Dichloroethene	75-35-4	µg/kg	c				240,000	1,100,000	93	NP	NP	93	20	15	5.0
1,2-Dichloroethene (cis)	156-59-2	µg/kg	nc				160,000	2,000,000	8.2	NP	NP	8.2	40	30	10
1,2-Dichloroethene (trans)	156-60-5	µg/kg	nc				150,000	690,000	25	NP	NP	25	40	30	10
1,2-Dichloropropane	78-87-5	µg/kg	c	61,000			940	4,700	0.13	NP	NP	0.13	12	10	3.9
1,3-Dichloropropane	142-28-9	µg/kg	nc	36,000			1,600,000	20,000,000	99	NP	NP	99	40	30	10
2,2-Dichloropropane	594-20-7	µg/kg	-	61,000	120	61,000	NS	NS	NS	NP	NP	NS	40	30	10
1,1-Dichloropropene	563-58-6	µg/kg	-	36,000	130	90,000	NS	NS	NS	NP	NP	NS	40	30	10
1,3-Dichloropropene (cis)	10061-01-5	µg/kg	-	8,000	7	310,000	NS	NS	NS	NP	NP	7	16	10	4.0
1,3-Dichloropropene (trans)	10061-02-6	µg/kg	-	36,000	36	90,000	NS	NS	NS	NP	NP	36	16	10	4.0
1,3-Dichloropropene (total)	542-75-6	µg/kg	c	36,000			1,700	8,300	0.15	NP	NP	0.15	32	20	8.0
Ethylbenzene	100-41-4	µg/kg	c				5,400	27,000	1.5	NP	NP	1.5	40	30	10
Hexachlorobutadiene	87-68-3	µg/kg	c				6,200	22,000	0.50	NP	NP	0.50	40	30	10
2-Hexanone	591-78-6	µg/kg	nc				210,000	1,400,000	7.9	NP	NP	7.9	200	150	50
Isopropylbenzene (Cumene)	98-82-8	µg/kg	nc				2,100,000	11,000,000	640	NP	NP	640	40	30	10
p-Isopropyltoluene (Cymene)	99-87-6	µg/kg	-	8,200,000	230,000	NP	NS	NS	NS	NP	NP	NS	40	30	10
4-Methyl-2-pentanone (Methyl isobutyl ketone)	108-10-1	µg/kg	nc				5,300,000	53,000,000	230	NP	NP	230	200	150	50
Methylene chloride	75-09-2	µg/kg	c				56,000	960,000	2.5	NP	NP	2.5	40	30	10
Methyl-tertiary-butyl ether	1634-04-4	µg/kg	c				43,000	220,000	2.8	NP	NP	2.8	40	30	10
Naphthalene	91-20-3	µg/kg	nc				3,600	18,000	0.47	NP	NP	0.47	40	30	10
n-Propylbenzene	103-65-1	µg/kg	nc				3,400,000	21,000,000	990	NP	NP	990	40	30	10
Styrene	100-42-5	µg/kg	nc				6,300,000	36,000,000	1,200	NP	NP	1,200	40	30	10
1,1,1,2-Tetrachloroethane	630-20-6	µg/kg	c				1,900	9,300.00	0.19	NP	NP	0.19	40	30	10
1,1,2,2-Tetrachloroethane	79-34-5	µg/kg	c				560	2,800	0.026	NP	NP	0.026	10	8.8	3.3
Tetrachloroethene (PCE)	127-18-4	µg/kg	c				22,000	110,000	4.4	NP	NP	4.4	20	15	5.0
Toluene	108-88-3	µg/kg	nc				5,000,000	45,000,000	590	NP	NP	590	40	30	10
1,2,3-Trichlorobenzene	87-61-6	µg/kg	nc				49,000	490,000	15	NP	NP	15	40	30	10
1,2,4-Trichlorobenzene	120-82-1	µg/kg	nc				22,000	99,000	2.9	NP	NP	2.9	40	30	10
1,1,1-Trichloroethane	71-55-6	µg/kg	nc				8,700,000	38,000,000	2,600	NP	NP	2,600	40	30	10
1,1,2-Trichloroethane	79-00-5	µg/kg	c				1,100	5,300	0.077	NP	NP	0.077	12	8.8	3.0
Trichloroethene (TCE)	79-01-6	µg/kg	c				910	6,400	0.16	NP	NP	0.16	16	10	4.0
Trichlorofluoromethane	75-69-4	µg/kg	nc				790,000	3,400,000	690	NP	NP	690	40	30	10
1,2,3-Trichloropropane	96-18-4	µg/kg	c				5.0	95	0.00028	NP	NP	0.00028	40	30	12
1,2,4-Trimethylbenzene	95-63-6	µg/kg	nc				62,000	260,000	21	NP	NP	21	40	30	10
1,3,5-Trimethylbenzene	108-67-8	µg/kg	nc				780,000	10,000,000	120	NP	NP	120	40	30	10
Vinyl chloride	75-01-4	µg/kg	c				60	1,700	0.0053	NP	NP	0.0053	8.0	5.0	2.0
m- & p-Xylenes	179601-23-1	µg/kg	nc				590,000	2,500,000	180	NP	NP	180	40	30	10
o-Xylene	95-47-6	µg/kg	nc				690,000	3,000,000	190	NP	NP	190	40	30	10
Xylenes (total)	1330-20-7	µg/kg	nc				630,000	2,700,000	190	NP	NP	190	80	60	20
Semivolatile Organic Compounds															
Benzoic acid	65-85-0	µg/kg	nc				240,000,000	2,500,000,000	14,000	NP	NP	14,000	2,500	1,000	750
Benzyl alcohol	100-51-6	µg/kg	nc				6,100,000	62,000,000	370	NP	NP	370	100	20	15
Bis(2-chloroethoxy)methane	111-91-1	µg/kg	nc				180,000	1,800,000	11	NP	NP	11	100	10	5.0
Bis(2-chloroethyl)ether	111-44-4	µg/kg	c				210	1,000	0.0031	NP	NP	0.0031	100	20	15
Bis(2-chloroisopropyl) ether	108-60-1	µg/kg	c				4,600	22,000	0.11	NP	NP	0.11	250	20	15
Bis(2-ethylhexyl) phthalate	117-81-7	µg/kg	c				35,000	120,000	17	NP	NP	17	600	100	50
4-Bromophenyl phenyl ether	101-55-3	µg/kg	-	280	350	9,800	NS	NS	NS	NP	NP	NS	100	20	15
Butyl benzyl phthalate	85-68-7	µg/kg	c				260,000	910,000	200	NP	NP	200	200	100	50
Carbazole	86-74-8	µg/kg	c	230,000	4,600	NP	NS	NS	NS	NP	NP	4,600	100	10	5.0
4-Chloro-3-methylphenol (p-chloro-m-Cresol)	59-50-7	µg/kg	nc				6,100,000	62,000,000	1,300	NP	NP	1,300	100	20	15
4-Chloroaniline	106-47-8	µg/kg	c				2,400	8,600	0.13	NP	NP	0.13	100	20	15
2-Chloronaphthalene	91-58-7	µg/kg	nc				6,300,000	82,000,000	2,900	NP	NP	2,900	20	10	5.0
2-Chlorophenol	95-57-8	µg/kg	nc				390,000	5,100,000	57	NP	NP	57	100	20	15
4-Chlorophenyl phenyl ether	7005-72-3	µg/kg	-	160	32	2,500	NS	NS	NS	NP	NP	NS	100	20	15
Dibenzofuran	132-64-9	µg/kg	nc				78,000	1,000,000	110	NP	NP	110	100	10	5.0
3,3-Dichlorobenzidine	91-94-1	µg/kg	c				1,100	3,800	0.71	NP	NP	0.71	200	40	30
2,4-Dichlorophenol	120-83-2	µg/kg	nc				180,000	1,800,000	41	NP	NP	41	100	20	15
Diethyl phthalate	84-66-2	µg/kg	nc				49,000,000	490,000,000	4,700	NP	NP	4,700	200	20	15
2,4-Dimethylphenol	105-67-9	µg/kg	nc				1,200,000	12,000,000	320	NP	NP	320	100	20	15
4,6-Dinitro-2-methylphenol (4,6-Dinitro-o-cresol)	534-52-1	µg/kg	nc				4,900	49,000	2.0	NP	NP	2.0	1,000	250	100
2,4-Dinitrophenol	51-28-5	µg/kg	nc				120,000	1,200,000	34	NP	NP	34	1,000	500	200
2,4-Dinitrotoluene	121-14-2	µg/kg	nc				1,600	5,500	0.28	NP	NP	0.28	100	20	15
2,6-Dinitrotoluene	606-20-2	µg/kg	c				61,000	620,000	20	NP	NP	20.0	100	20	15
Dimethyl phthalate	131-11-3	µg/kg	nc	53,000,000	62,000	NP	NS	NS	NS	NP	NP	62,000	100	10	5.0
Di-n-butyl phthalate	84-74-2	µg/kg	nc	6,200,000	3,300,000	NP	6,100,000	62,000,000	1,700	NP	NP	1,700	500	100	50
Di-n-octyl phthalate	117-84-0	µg/kg	nc	2,600,000	1,000,000,000	NP	NS	NS	NS	NP	NP	2,600,000	500	10	5.0
Hexachlorobenzene	118-74-1	µg/kg	c				300	1,100	0.53	NP	NP	0.53	50	10	5.0
Hexachlorocyclopentadiene	77-47-4	µg/kg	nc				370,000	3,700,000	70	NP	NP	70	100	10	5.0
Hexachloroethane	67-72-1	µg/kg	c				12,000	43,000	0.48	NP	NP	0.48	100	20	15
Isophorone	78-59-1	µg/kg	c				510,000	1,800,000	22	NP	NP	22	100	10	5.0
2-Methylphenol	95-48-7	µg/kg	c				3,100,000	31,000,000	580	NP	NP	580	100	20	15
3- & 4-Methylphenols	15831-10-4	µg/kg	c				3,100,000	31,000,000	570	NP	NP	570	200	20	15
2-Nitroaniline	88-74-4	µg/kg	nc	14,000			610,000	6,000,000	62	NP	NP	62	100	20	15
3-Nitroaniline	99-09-2	µg/kg	-	15,000	26	60,000	NS	NS	NS	NP	NP	26	100	20	15
4-Nitroaniline	100-01-6	µg/kg	c	220,000			24,000	86,000	1.4	NP	NP	1.4	100	20	15
Nitrobenzene	98-95-3	µg/kg	nc	66,000			4,800	24,000	0.079	NP	NP	0.079	100	50	34
2-Nitrophenol	88-75-5	µg/kg	-	130,000	130	NP	NS	NS	NS	NP	NP	NS	100	20	15
4-Nitrophenol	100-02-7	µg/kg	-	130,000	100	NP	NS	NS	NS	NP	NP	100	1,000	500	250
N-Nitrosodimethylamine	62-75-9	µg/kg	c	74			2.3	34	0.00010	NP	NP	0.00010	1,000	500	250
N-Nitrosodi-n-propylamine	621-64-7	µg/kg	c	400			69	250	0.0070	NP	NP	0.0070	100	20	15
N-Nitrosodiphenylamine	86-30-6	µg/kg	c	570,000			99,000	350,000	57	NP	NP	57	50	10	5.0
Pentachlorophenol	87-86-5	µg/kg	c				890	2,700	1.7	2.1	Based on avian receptors (2.8 for mammalian)	1.7	200	50	20
Phenol	108-95-2	µg/kg	nc				18,000,000	180,000,000	2,600	NP	NP	2,600	100	20	15
1,2,4-Trichlorobenzene	120-82-1	µg/kg	nc				22,000	99,000	2.9	NP	NP	2.9	50	20	15
2,4,5-Trichlorophenol	95-95-4	µg/kg	nc				6,100,000	62,000,000	3,300	NP	NP	3,300	100	20	15
2,4,6-Trichlorophenol	88-06-2	µg/kg	c				44,000	160,000	13	NP	NP	13	150	20	15
Polycyclic Aromatic Hydrocarbons															
Acenaphthene	83-32-9	µg/kg	nc	3,000,000			3,400,000	33,000,000	4,100	1,100	HMW-PAH based on mammalian receptors (18,000 for soil invertebrates)	1,100	5.0	2.5	1.5
Acenaphthylene	208-96-8	µg/kg	nc	3,800,000	410,000	NP	NS	NS	NS	1,100	HMW-PAH based on mammalian receptors (18,000 for soil invertebrates)	1,100	5.0	2.5	1.5
Anthracene	120-12-7	µg/kg	nc	18,000,000			17,000,000	170,000,000	42,000	29,000	LMW-PAH based on soil invertebrates (100,000 for mammalian)	29,000	5.0	2.5	1.5
Benzo(a)anthracene	56-55-3	µg/kg	c	5,700			150	2,100	10	1,100	HMW-PAH based on mammalian receptors (18,000 for soil invertebrates)	10	5.0	2.5	1.5
Benzo(b)fluoranthene	205-99-2	µg/kg	c	5,700			150	2,100	35	1,100	HMW-PAH based on mammalian receptors (18,000 for soil invertebrates)	35	5.0	2.5	1.5
Benzo(k)fluoranthene	207-08-9	µg/kg	c	5,700			1,500	21,000	350	1,100	HMW-PAH based on mammalian receptors (18,000 for soil invertebrates)	350	5.0	2.5	1.5
Benzo(g,h,i)perylene	191-24-2	µg/kg	nc	1,800,000	46,000,000	NP	NS	NS	NS	1,100	HMW-PAH based on mammalian receptors (18,000 for soil invertebrates)	1,100	5.0	2.5	1.5

TABLE A-3. REFERENCE LIMITS AND PROJECT ACTION LIMITS FOR SURFACE AND SUBSURFACE SOIL, FALCON REFINERY SUPERFUND SITE

Analyte	CASRN	Units	c/nc	TCEQ TRRP Residential Levels[1]			USEPA Regional Screening Levels [5]					PAL [10]	Achievable Laboratory Limits (TestAmerica,		
				TotSoil Comb	GWSoil Ing	AirSoil Inh-V	Residential	Industrial	Protection of Ground Water	USEPA Eco-SSL Lowest Value [8]	USEPA Eco-SSL Additional Values [8]		LOQ	LOD	DL
Benzo(a)pyrene	50-32-8	µg/kg	c	560			15	210	3.5	1,100	HMW-PAH based on mammalian receptors (18,000 for soil invertebrates)	3.5	**5.0**	2.5	1.5
Chrysene	218-01-9	µg/kg	c	560,000			15,000	210,000	1,100	1,100	HMW-PAH based on mammalian receptors (18,000 for soil invertebrates)	1,100	5.0	5.0	1.5
Dibenz(a,h)anthracene	53-70-3	µg/kg	c	550			15	210	11	1,100	HMW-PAH based on mammalian receptors (18,000 for soil invertebrates)	11	5.0	2.5	1.5
Fluoranthene	206-44-0	µg/kg	nc	2,300,000			2,300,000	22,000,000	70,000	29,000	LMW-PAH based on soil invertebrates (100,000 for mammalian)	29,000	5.0	2.5	1.5
Fluorene	86-73-7	µg/kg	nc	2,300,000			2,300,000	22,000,000	4,000	29,000	LMW-PAH based on soil invertebrates (100,000 for mammalian)	4,000	5.0	2.5	1.5
Indeno(1,2,3-cd)pyrene	193-39-5	µg/kg	c	5,700			150	2,100	120	29,000	HMW-PAH based on mammalian receptors (18,000 for soil invertebrates)	120	5.0	2.5	1.5
1-Methylnaphthalene	90-12-0	µg/kg	nc	150,000			16,000	53,000	5.1	29,000	LMW-PAH based on soil invertebrates (100,000 for mammalian)	5.1	5.0	5.0	1.5
2-Methylnaphthalene	91-57-6	µg/kg	nc	250,000			230,000	2,200,000	140	29,000	LMW-PAH based on soil invertebrates (100,000 for mammalian)	140	5.0	5.0	2.0
6-Methyl Chrysene	1705-85-7	µg/kg		57,000	1,800,000	1,000,000,000	NS	NS	NS	NP	NP	--	--	--	--
Naphthalene	91-20-3	µg/kg	nc	220,000			3,600	18,000	0.47	29,000	LMW-PAH based on soil invertebrates (100,000 for mammalian)	0.47	**5.0**	**5.0**	**2.0**
Phenanthrene	85-01-8	µg/kg	nc	1,700,000	420,000	NP	NS	NS	NS	29,000	LMW-PAH based on soil invertebrates (100,000 for mammalian)	29,000	5.0	2.5	1.5
Pyrene	129-00-0	µg/kg	nc	1,700,000			1,700,000	17,000,000	9,500	1,100	HMW-PAH based on mammalian receptors (18,000 for soil invertebrates)	1,100	5.0	2.5	1.5
Organochlorine Pesticides															
Aldrin	309-00-2	µg/kg	c	50			29	100	0.034	NP	NP	0.034	**1.0**	**0.30**	**0.22**
alpha-BHC	319-84-6	µg/kg	c	260			77	270	0.036	NP	NP	0.036	**1.0**	**0.30**	**0.28**
beta-BHC	319-85-7	µg/kg	c	930			270	960	0.13	NP	NP	0.13	**1.0**	**0.50**	**0.32**
delta-BHC	319-86-8	µg/kg	-	2,900	170	100,000	NS	NS	NS	NP	NP	NS	1.0	0.30	0.15
gamma-BHC (Lindane)	58-89-9	µg/kg	c	1,100			520	2,100	0.21	NP	NP	0.21	**1.0**	**0.30**	**0.30**
alpha-Chlordane	5103-71-9	µg/kg	c	13,000			1,600	6,500	1.8	NP	NP	1.8	1.0	0.30	0.13
gamma-Chlordane	5103-74-2	µg/kg	c	7,400			1,600	6,500	1.8	NP	NP	1.8	1.0	0.30	0.13
4,4-DDD	72-54-8	µg/kg	c				2,000	7,200	66	NP	NP	66	2.0	0.30	0.15
4,4-DDE	72-55-9	µg/kg	c				1,400	5,100	46	NP	NP	46	2.0	0.30	0.14
4,4-DDT	50-29-3	µg/kg	c				1,700	7,000	67	21	Based on mammalian receptors (93 for avian)	21.0	2.0	0.30	0.15
Dieldrin	60-57-1	µg/kg	c				30	110	0.061	4.9	Based on mammalian receptors (22 for avian)	0.061	**2.0**	**0.30**	**0.12**
Endosulfan I	959-98-8	µg/kg	nc				370,000	3,700,000	1,100	NP	NP	1,100	1.0	0.30	0.10
Endosulfan II	33213-65-9	µg/kg	nc				370,000	3,700,000	1,100	NP	NP	1,100	2.0	0.30	0.17
Endosulfan sulfate	1031-07-8	µg/kg	nc				370,000	3,700,000	1,100	NP	NP	1,100	2.0	0.30	0.19
Endrin	72-20-8	µg/kg	nc	9,000			18,000	180,000	68	NP	NP	68.0	**2.0**	0.30	0.16
Endrin aldehyde	7421-93-4	µg/kg	nc	19,000	630,000	NP	NS	NS	NS	NP	NP	19,000	2.0	0.30	0.20
Endrin ketone	53494-70-5	µg/kg	nc	19,000	51,000	NP	NS	NS	NS	NP	NP	NS	2.0	0.50	0.26
Heptachlor	76-44-8	µg/kg	c				110	380	0.14	NP	NP	0.14	**1.0**	**0.50**	**0.46**
Heptachlor epoxide	1024-57-3	µg/kg	c				53	190	0.068	NP	NP	0.06800	**1.0**	**0.30**	**0.0030**
Methoxychlor	72-43-5	µg/kg	nc				310,000	3,100,000	1,500	NP	NP	1,500	10	0.30	0.26
Toxaphene	8001-35-2	µg/kg	c				440	1,600	2.1	NP	NP	2.1	**100**	**50**	**10**
Polychlorinated Biphenyls (PCBs)															
Aroclor 1016	12674-11-2	µg/kg	nc				3,900	21,000	92	NP	NP		10	5.0	3.2
Aroclor 1221	11104-28-2	µg/kg	c				140	540	0.074	NP	NP		10	8.0	8.0
Aroclor 1232	11141-16-5	µg/kg	c				140	540	0.074	NP	NP		10	8.0	7.0
Aroclor 1242	53469-21-9	µg/kg	c				220	740	5.3	NP	NP		10	5.0	2.1
Aroclor 1248	12672-79-6	µg/kg	c				220	740	5.2	NP	NP		10	3.0	3.0
Aroclor 1254	11097-69-1	µg/kg	c				220	740	8.8	NP	NP		10	5.0	2.1
Aroclor 1260	11096-82-5	µg/kg	c				220	740	24	NP	NP		10	5.0	3.0
Total PCBs	1336-36-3	µg/kg	c				220	740	NS	NP	NP		10	8.0	8.0
Total Metals															
Aluminum	7429-90-5	mg/kg	nc	65,000			77,000	990,000	23,000	NP	Not enough information to provide an Eco-SSL, instead if pH<5.5 then aluminum may be of concern	23,000.0	**50**	**10**	**8.9**
Antimony	7440-36-0	mg/kg	nc	15			31	410	0.27	0.27	Based on mammalian (78 for soil invertebrates)	0.27	**0.20**	0.080	0.042
Arsenic	7440-38-2	mg/kg	c	24			0.39	1.6	0.0013	18	Based on terrestrial plants (43 for avian, 46 for mammalian)	0.0013	**0.50**	**0.40**	**0.18**
Barium	7440-39-3	mg/kg	nc	8,100			15,000	190,000	120	330	Based on soil invertebrates (2,000 for mammalian)	120.0	0.20	0.040	0.030
Beryllium	7440-41-7	mg/kg	c	38			160	2,000	13	21	Based on mammalian (40 for soil invertebrates)	13.0	0.20	0.040	0.022
Cadmium	7440-43-9	mg/kg	c	52			70	800	0.52	0.36	Based on mammalian (0.77 for avian receptors, 32 for plants, 140 for soil invertebrates)	0.3600	**0.20**	**0.020**	**0.0080**
Calcium	7440-70-2	mg/kg	-	1,000,000	1,000,000	1,000,000	NS	NS	NS	NP	NP	NS	55	7.5	5.2
Chromium	7440-47-3	mg/kg	nc	Cr III = 33,000 Cr VI = 120 Cr Total =33,000			Cr VI = 0.29	Cr VI = 5.6	Cr VI = 0.00059	Cr III = 26 CrVI = 130	CrIII based on avian (34 for mammalian) and CrVI based on mammalian	0.00000	**0.20**	**0.15**	**0.11**
Cobalt	7440-48-4	mg/kg	nc	21			23	300	0.21	13	Based on terrestrial plants (120 for avian and 230 for mammalian)	0.21	**0.20**	0.040	0.019
Copper	7440-50-8	mg/kg	nc	550			3,100	41,000	22	28	Based on avian receptors (49 for mammalian, 70 for plants, and 80 for soil invertebrates)	22.0	0.40	0.20	0.098
Iron	7439-89-6	mg/kg	nc	1,000,000			55,000	720,000	270	NE	A determination of the geochemical conditions (i.e., pH and Eh at a minimum) of the environmental setting, as well as the presence of iron floc and the toxic metals, is critical to the determination of the relative importance of iron at a site.	270	10	5.0	3.6
Lead	7439-92-1	mg/kg	-	500			400	800	NS	11	Based on avian receptors (56 for mammalian, 120 for plants, and 1,700 for soil invertebrates)	11.000	**0.20**	0.020	0.013
Magnesium	7439-95-4	mg/kg	-	1,000,000	1,000,000	1,000,000	NS	NS	NS	NP	NP	NS	55	4.0	3.2
Manganese	7439-96-5	mg/kg	nc	3,700			1,800	23,000	21	220	Based on terrestrial plants (450 for soil invertebrates, 4,000 for mammalian, and 4,300 for avian)	21	0.50	0.20	0.17
Mercury	7439-97-6	mg/kg	nc	3.6			10	43	0.033	0.1	This value is from Table 3 of "Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision"	0.033	0.020	0.010	0.0063
Nickel	7440-02-0	mg/kg	nc	840			1,500	20,000	20	38	Based on terrestrial plants (130 for mammalian, 210 for avian, and 280 for soil invertebrates)	20	0.50	0.25	0.071
Potassium	7440-09-7	mg/kg	-	1,000,000	1,000,000	1,000,000	NS	NS	NS	NP	NP	NS	165	20	16
Selenium	7782-49-2	mg/kg	nc	310			390	5,100	0.40	0.52	Based on terrestrial plants (0.63 for mammalian, 1.2 for avian, and 4.1 for soil invertebrates)	0.400	**0.70**	**0.40**	**0.20**
Silver	7440-22-4	mg/kg	nc	97			390	5,100	0.60	4.2	Based on avian receptors (14 for mammalian and 560 for plants)	0.60	0.20	0.020	0.012
Sodium	7440-23-5	mg/kg	-	1,000,000	1,000,000	1,000,000	NS	NS	NS	NP	NP	NS	100	15	15
Thallium	7440-28-0	mg/kg	nc	6.3			0.78	10	0.011	NP	NP	0.011	**0.50**	**0.26**	**0.13**
Vanadium	7440-62-2	mg/kg	nc	76			390	5,200	78	7.8	Based on avian receptors (280 for mammalian)	7.8	0.70	0.50	0.47
Zinc	7440-66-6	mg/kg	nc	9,900			23,000	310,000	290	46	Based on avian receptors (79 for mammalian, 120 for soil invertebrates, and 160 for plants)	46.00	**2.0**	**1.5**	**1.1**

Notes:
c - carcinogenic; nc - noncarcinogenic
Analytes shown in bold and highlight have a PAL lower than or equal to the LOQ/LOD/DL.
[1] TCEQ TRRP Table 1 Tier 1 Residential Soil PCLs, June 29, 2012
[5] USEPA May 2012 RSLs as presented at the following website at http://www.epa.gov/region9/superfund/prg/.
[6] Ecological screening levels for soil are only applicable to surface or shallow subsurface soil.
[7] The lowest ecological risk soil screening value from the Risk Assessment Information System (RAIS) database, found at http://rais.ornl.gov/tools/eco_search.php and accessed July 2012.
[8] USEPA 2012b. Ecological Soil Screening Levels. http://www.epa.gov/ecotox/ecossl/. Accessed on 19 June 2012.
[10] PALs refer to the lowest applicable screening level.

µg/kg = microgram(s) per kilogram
LOD = limit of detection
NP = contaminant and screening limit not provided in guidance
CASRN = Chemical Abstracts Service Registry Number
LOQ = limit of quantitation
NS = not specified
RSL = Regional Screening Level
DL = detection limit
mg/kg = milligram(s) per kilogram
PAL = project action limit
SIM = selected ion monitoring
Eco-SSL = Ecological Soil Screening Levels
NA = not applicable
RRO = residual range organics
USEPA = U.S. Environmental Protection Agency
ERBSC = Ecological Risk Based Screening Concentration
NE = contaminant listed in guidance but not enough information to establish a screening limit

TABLE A-4. REFERENCE LIMITS AND PROJECT ACTION LIMITS FOR SEDIMENT
FALCON REFINERY SUPERFUND SITE

Analyte	CASRN	Units	c/nc	TCEQ TRRP Residential[1] TotSoil Comb	USEPA Regional Screening Level[2]	Protection of Benthic Invertebrates Screening Level[3]	PAL[4]	Achievable Laboratory Limits (TestAmerica Tacoma)			
								Analytical Method	LOQ	LOD	DL
Volatile Organic Compounds											
Acetone	67-64-1	µg/kg	nc	66,000,000	61,000,000	NS	61,000,000	SW8260B	400	300	100
Benzene	71-43-2	µg/kg	c	120,000	1,100	10	10	SW8260B	16	10	4.0
Bromobenzene	108-86-1	µg/kg	nc	390,000	300,000	NS	300,000	SW8260B	40	30	10
Bromochloromethane	74-97-5	µg/kg	nc		160,000	NS	160,000	SW8260B	40	30	12
Bromodichloromethane	75-27-4	µg/kg	c	98,000	270	NS	270	SW8260B	40	30	10
Bromoform	75-25-2	µg/kg	c	400,000	62,000	NS	62,000	SW8260B	40	30	11
Bromomethane (Methyl bromide)	74-83-9	µg/kg	nc	46,000	7,300	NS	7,300	SW8260B	140	100	35
2-Butanone (Methyl ethyl ketone)	78-93-3	µg/kg	nc	4,000,000	28,000,000	NS	4,000,000	SW8260B	400	300	100
n-Butylbenzene	104-51-8	µg/kg	nc	3,300,000	3,900,000	NS	3,300,000	SW8260B	40	30	10
sec-Butylbenzene	135-98-8	µg/kg	nc	3,300,000	NS	NS	3,300,000	SW8260B	40	30	10
t-Butylbenzene	98-06-6	µg/kg	nc	3,300,000	NS	NS	3,300,000	SW8260B	40	30	10
Carbon disulfide	75-15-0	µg/kg	nc		820,000	NS	820,000	SW8260B	40	30	10
Carbon tetrachloride	56-23-5	µg/kg	c		610	170	170	SW8260B	20	15	5.0
Chlorobenzene	108-90-7	µg/kg	nc		290,000	30	30	SW8260B	40	30	10
Chloroethane (Ethyl chloride)	75-00-3	µg/kg	c		15,000,000	NS	15,000,000	SW8260B	400	300	100
Chloroform	67-66-3	µg/kg	c		290	20	20	SW8260B	40	30	10
Chloromethane (Methyl chloride)	74-87-3	µg/kg	c		120,000	NS	120,000	SW8260B	400	300	100
2-Chlorotoluene	95-49-8	µg/kg	nc		1,600,000	NS	1,600,000	SW8260B	40	30	10
4-Chlorotoluene	106-43-4	µg/kg	nc		1,600,000	NS	1,600,000	SW8260B	40	30	13
1,2-Dibromo-3-chloropropane (DBCP)	96-12-8	µg/kg	c		5.4	NS	5	SW8260B	200	150	66
Dibromochloromethane (Chlorodibromomethane)	124-48-1	µg/kg	c		680	NS	680	SW8260B	40	30	10
1,2-Dibromoethane (Ethylene dibromide [EDB])	106-93-4	µg/kg	c		34	NS	34	SW8260B	40	30	10
Dibromomethane (Methylene bromide)	74-95-3	µg/kg	nc		25,000	NS	25,000	SW8260B	40	30	10
1,2-Dichlorobenzene	95-50-1	µg/kg	nc	720,000	1,900,000	30	30	SW8260B	40	30	10
1,3-Dichlorobenzene	541-73-1	µg/kg	nc	120,000	NS	30	30	SW8260B	40	30	10
1,4-Dichlorobenzene	106-46-7	µg/kg	c	250,000	2,400	30	30	SW8260B	40	30	10
Dichlorodifluoromethane	75-71-8	µg/kg	nc		94,000	NS	94,000	SW8260B	40	30	10
1,1-Dichloroethane	75-34-3	µg/kg	c		3,300	20	20	SW8260B	40	30	10
1,2-Dichloroethane	107-06-2	µg/kg	c		430	20	20	SW8260B	40	30	10
1,1-Dichloroethene	75-35-4	µg/kg	c		240,000	100	100	SW8260B	20	15	5.0
1,2-Dichloroethene (cis)	156-59-2	µg/kg	nc		160,000	200	200	SW8260B	40	30	10
1,2-Dichloroethene (trans)	156-60-5	µg/kg	nc		150,000	200	200	SW8260B	40	30	10
1,2-Dichloropropane	78-87-5	µg/kg	c	61,000	940	2.0	2	SW8260B	12	10	3.9
1,3-Dichloropropane	142-28-9	µg/kg	nc	36,000	1,600,000	NS	36,000	SW8260B	40	30	10
2,2-Dichloropropane	594-20-7	µg/kg	-	61,000	NS	NS	61,000	SW8260B	40	30	10
1,1-Dichloropropene	563-58-6	µg/kg	-	36,000	NS	NS	36,000	SW8260B	40	30	10
1,3-Dichloropropene (cis)	10061-01-5	µg/kg	-	8,000	NS	NS	8,000	SW8260B	16	10	4.0
1,3-Dichloropropene (trans)	10061-02-6	µg/kg	-	36,000	NS	NS	36,000	SW8260B	16	10	4.0
1,3-Dichloropropene (total)	542-75-6	µg/kg	c	36,000	1,700	NS	1,700	SW8260B	32	20	8.0
Ethylbenzene	100-41-4	µg/kg	c		5,400	30	30	SW8260B	40	30	10
Hexachlorobutadiene	87-68-3	µg/kg	c		6,200	NS	6,200	SW8260B	40	30	10
2-Hexanone	591-78-6	µg/kg	nc		210,000	NS	210,000	SW8260B	200	150	50
Isopropylbenzene (Cumene)	98-82-8	µg/kg	nc		2,100,000	NS	2,100,000	SW8260B	40	30	10
p-Isopropyltoluene	99-87-6	µg/kg	-	8,200,000	NS	NS	8,200,000	SW8260B	40	30	10
4-Methyl-2-pentanone (Methyl isobutyl ketone)	108-10-1	µg/kg	nc		5,300,000	NS	5,300,000	SW8260B	200	150	50
Methylene chloride	75-09-2	µg/kg	c		56,000	18	18	SW8260B	40	30	10
Methyl-tertiary-butyl ether	1634-04-4	µg/kg	c		43,000	NS	43,000	SW8260B	40	30	10
Naphthalene	91-20-3	µg/kg	nc		3,600	176	176	SW8260B	40	30	10
n-Propylbenzene	103-65-1	µg/kg	nc		3,400,000	NS	3,400,000	SW8260B	40	30	10
Styrene	100-42-5	µg/kg	nc		6,300,000	200	200	SW8260B	40	30	10
1,1,1,2-Tetrachloroethane	630-20-6	µg/kg	c		1,900	NS	1,900	SW8260B	40	30	10
1,1,2,2-Tetrachloroethane	79-34-5	µg/kg	c		560	NS	560	SW8260B	10	8.8	3.3
Tetrachloroethene (PCE)	127-18-4	µg/kg	c		22,000	2.0	2	SW8260B	20	15	5.0
Toluene	108-88-3	µg/kg	nc		5,000,000	NS	5,000,000	SW8260B	40	30	10
1,2,3-Trichlorobenzene	87-61-6	µg/kg	nc		49,000	11	11	SW8260B	40	30	10
1,2,4-Trichlorobenzene	120-82-1	µg/kg	nc		22,000	11	11	SW8260B	40	30	10
1,1,1-Trichloroethane	71-55-6	µg/kg	nc		8,700,000	70	70	SW8260B	40	30	10
1,1,2-Trichloroethane	79-00-5	µg/kg	c		1,100	400	400	SW8260B	12	8.8	3.0
Trichloroethene (TCE)	79-01-6	µg/kg	c		910	7.8	8	SW8260B	16	10	4.0
Trichlorofluoromethane	75-69-4	µg/kg	nc		790,000	NS	790,000	SW8260B	40	30	10
1,2,3-Trichloropropane	96-18-4	µg/kg	c		5.0	NS	5	SW8260B	40	30	12
1,2,4-Trimethylbenzene	95-63-6	µg/kg	nc		62,000	NS	62,000	SW8260B	40	30	10
1,3,5-Trimethylbenzene	108-67-8	µg/kg	nc		780,000	NS	780,000	SW8260B	40	30	10
Vinyl chloride	75-01-4	µg/kg	c		60	10	10	SW8260B	8.0	5.0	2.0
m- & p-Xylenes	179601-23-1	µg/kg	nc		590,000	110	110	SW8260B	40	30	10
o-Xylene	95-47-6	µg/kg	nc		690,000	89	89	SW8260B	40	30	10
Xylenes (total)	1330-20-7	µg/kg	nc		630,000	130	130	SW8260B	80	60	20
Semivolatile Organic Compounds											
Benzoic acid	65-85-0	µg/kg	nc		410,000	NS	410,000	SW8270C	2,500	1,000	750
Benzyl alcohol	100-51-6	µg/kg	nc		NS	NS	0	SW8270C	100	20	15
Bis(2-chloroethoxy)methane	111-91-1	µg/kg	nc		NS	NS	0	SW8270C	100	10	5.0
Bis(2-chloroethyl)ether	111-44-4	µg/kg	c		2.2	NS	2	SW8270C	100	20	15
Bis(2-chloroisopropyl) ether	108-60-1	µg/kg	c		NS	NS	0	SW8270C	250	20	15
Bis(2-ethylhexyl) phthalate	117-81-7	µg/kg	c		13,000	100	100	SW8270C	600	100	50
4-Bromophenyl phenyl ether	101-55-3	µg/kg	-	280	NS	NS	280	SW8270C	100	20	15
Butyl benzyl phthalate	85-68-7	µg/kg	c		920,000	NS	920,000	SW8270C	200	100	50
Carbazole	86-74-8	µg/kg	c	230,000	6,500	NS	6,500	SW8270C	100	10	5.0
4-Chloro-3-methylphenol (p-chloro-m-Cresol)	59-50-7	µg/kg	nc		NS	NS	0	SW8270C	100	20	15
4-Chloroaniline	106-47-8	µg/kg	c		57	NS	57	SW8270C	100	20	15
2-Chloronaphthalene	91-58-7	µg/kg	nc		120,000	NS	120,000	SW8270C	20	10	5.0
2-Chlorophenol	95-57-8	µg/kg	nc		1,500	55	55	SW8270C	100	20	15
4-Chlorophenyl phenyl ether	7005-72-3	µg/kg	-	160	NS	NS	160	SW8270C	100	20	15
Dibenzofuran	132-64-9	µg/kg	nc		11,000	5,100	5,100	SW8270C	100	10	5.0
3,3-Dichlorobenzidine	91-94-1	µg/kg	c		190	NS	190	SW8270C	200	40	30

TABLE A-4. REFERENCE LIMITS AND PROJECT ACTION LIMITS FOR SEDIMENT FALCON REFINERY SUPERFUND SITE

Analyte	CASRN	Units	c/nc	TCEQ TRRP Residential[1] ^{Tot}Soil $_{Comb}$	USEPA Regional Screening Level[2]	Protection of Benthic Invertebrates Screening Level[3]	PAL[4]	Achievable Laboratory Limits (TestAmerica Tacoma)			
								Analytical Method	LOQ	LOD	DL
2,4-Dichlorophenol	120-83-2	µg/kg	nc		1,300	10	10	SW8270C	**100**	**20**	**15**
Diethyl phthalate	84-66-2	µg/kg	nc		130,000	530	530	SW8270C	200	20	15
2,4-Dimethylphenol	105-67-9	µg/kg	nc		8,800	NS	8,800	SW8270C	100	20	15
4,6-Dinitro-2-methylphenol (4,6-Dinitro-o-cresol)	534-52-1	µg/kg	nc		NS	NS	0	SW8270C	1,000	250	100
2,4-Dinitrophenol	51-28-5	µg/kg	nc		540	NS	540	SW8270C	1,000	500	200
2,4-Dinitrotoluene	121-14-2	µg/kg	nc		9.3	NS	9	SW8270C	**100**	**20**	**15**
2,6-Dinitrotoluene	606-20-2	µg/kg	c		9.4	NS	9	SW8270C	**100**	**20**	**15**
Dimethyl phthalate	131-11-3	µg/kg	nc	53,000,000	1,100,000	1,000	1,000	SW8270C	100	10	5.0
Di-n-butyl phthalate	84-74-2	µg/kg	nc	6,200,000	80,000	110	110	SW8270C	500	100	50
Di-n-octyl phthalate	117-84-0	µg/kg	nc	2,600,000	3,800,000	100	100	SW8270C	500	10	5.0
Hexachlorobenzene	118-74-1	µg/kg	c		47	1.4	1	SW8270C	**50**	**10**	**5.0**
Hexachlorocyclopentadiene	77-47-4	µg/kg	nc		1,300	NS	1,300	SW8270C	100	10	5.0
Hexachloroethane	67-72-1	µg/kg	c		210	NS	210	SW8270C	100	20	15
Isophorone	78-59-1	µg/kg	c		3,100	NS	3,100	SW8270C	100	10	5.0
2-Methylphenol	95-48-7	µg/kg	c		15,000	500	500	SW8270C	100	20	15
3- & 4-Methylphenols	15831-10-4	µg/kg	c		1,500	5.1	5	SW8270C	**200**	**20**	**15**
2-Nitroaniline	88-74-4	µg/kg	nc	14,000	NS	NS	14,000	SW8270C	100	20	15
3-Nitroaniline	99-09-2	µg/kg	-	15,000	NS	NS	15,000	SW8270C	100	20	15
4-Nitroaniline	100-01-6	µg/kg	c	220,000	NS	NS	220,000	SW8270C	100	20	15
Nitrobenzene	98-95-3	µg/kg	nc	66,000	94	NS	94	SW8270C	100	50	34
2-Nitrophenol	88-75-5	µg/kg	-	130,000	NS	NS	130,000	SW8270C	100	20	15
4-Nitrophenol	100-02-7	µg/kg	-	130,000	NS	NS	130,000	SW8270C	1,000	500	250
N-Nitrosodimethylamine	62-75-9	µg/kg	c	74	0.053	NS	0	SW8270C	**1,000**	**500**	**250**
N-Nitrosodi-n-propylamine	621-64-7	µg/kg	c	400	1.1	NS	1	SW8270C	**100**	**20**	**15**
N-Nitrosodiphenylamine	86-30-6	µg/kg	c	570,000	15,000	NS	15,000	SW8270C	50	10	5.0
Pentachlorophenol	87-86-5	µg/kg	c		47	10	10	SW8270C	**200**	**50**	**20**
Phenol	108-95-2	µg/kg	nc		68,000	48	48	SW8270C	100	20	15
1,2,4-Trichlorobenzene	120-82-1	µg/kg	nc		850	11	11	SW8270C	**50**	**20**	**15**
2,4,5-Trichlorophenol	95-95-4	µg/kg	nc		67,000	10	10	SW8270C	**100**	**20**	**15**
2,4,6-Trichlorophenol	88-06-2	µg/kg	c		1,400	10	10	SW8270C	**150**	**20**	**15**
Polycyclic Aromatic Hydrocarbons											
Acenaphthene	83-32-9	µg/kg	nc	3,000,000	3,400,000	6.7	7	SW8270C SIM	5.0	2.5	1.5
Acenaphthylene	208-96-8	µg/kg	nc	3,800,000	NS	5.9	6	SW8270C SIM	5.0	2.5	1.5
Anthracene	120-12-7	µg/kg	nc	18,000,000	17,000,000	57	57	SW8270C SIM	5.0	2.5	1.5
Benzo(a)anthracene	56-55-3	µg/kg	c	5,700	150	108	108	SW8270C SIM	5.0	2.5	1.5
Benzo(b)fluoranthene	205-99-2	µg/kg	c	5,700	150	NS	150	SW8270C SIM	5.0	2.5	1.5
Benzo(k)fluoranthene	207-08-9	µg/kg	c	5,700	1,500	27	27	SW8270C SIM	5.0	2.5	1.5
Benzo(g,h,i)perylene	191-24-2	µg/kg	nc	1,800,000	NS	170	170	SW8270C SIM	5.0	2.5	1.5
Benzo(a)pyrene	50-32-8	µg/kg	c	560	15	150	15	SW8270C SIM	5.0	2.5	1.5
Chrysene	218-01-9	µg/kg	c	560,000	15,000	166	166	SW8270C SIM	5.0	5.0	1.5
Dibenz(a,h)anthracene	53-70-3	µg/kg	c	550	15	33	15	SW8270C SIM	5.0	2.5	1.5
Fluoranthene	206-44-0	µg/kg	nc	2,300,000	2,300,000	423	423	SW8270C SIM	5.0	2.5	1.5
Fluorene	86-73-7	µg/kg	nc	2,300,000	2,300,000	77	77	SW8270C SIM	5.0	2.5	1.5
Indeno(1,2,3-cd)pyrene	193-39-5	µg/kg	c	5,700	150	17	17	SW8270C SIM	5.0	2.5	1.5
1-Methylnaphthalene	90-12-0	µg/kg	nc	150,000	16,000	NS	16,000	SW8270C SIM	5.0	5.0	1.5
2-Methylnaphthalene	91-57-6	µg/kg	nc	250,000	230,000	NS	230,000	SW8270C SIM	5.0	5.0	2.0
Naphthalene	91-20-3	µg/kg	nc	220,000	3,600	176	176	SW8270C SIM	5.0	5.0	2.0
Phenanthrene	85-01-8	µg/kg	nc	1,700,000	NS	204	204	SW8270C SIM	5.0	2.5	1.5
Pyrene	129-00-0	µg/kg	nc	1,700,000	1,700,000	195	195	SW8270C SIM	5.0	2.5	1.5
Organochlorine Pesticides											
Aldrin	309-00-2	µg/kg	c	50	29	0.060	0	SW8081A	**1.0**	**0.30**	**0.22**
alpha-BHC	319-84-6	µg/kg	c	260	77	3.0	3	SW8081A	1.0	0.30	0.28
beta-BHC	319-85-7	µg/kg	c	930	270	5.0	5	SW8081A	1.0	0.50	0.32
delta-BHC	319-86-8	µg/kg	-	2,900	NS	10	10	SW8081A	1.0	0.30	0.15
gamma-BHC (Lindane)	58-89-9	µg/kg	c	1,100	520	3.7	4	SW8081A	1.0	0.30	0.30
alpha-Chlordane	5103-71-9	µg/kg	c	13,000	1,600	3.2	3	SW8081A	**1.0**	**0.30**	**0.13**
gamma-Chlordane	5103-74-2	µg/kg	c	7,400	1,600	3.2	3	SW8081A	**1.0**	**0.30**	**0.13**
4,4-DDD	72-54-8	µg/kg	c		2,000	4.9	5	SW8081A	**2.0**	**0.30**	**0.15**
4,4-DDE	72-55-9	µg/kg	c		1,400	3.2	3	SW8081A	**2.0**	**0.30**	**0.14**
4,4-DDT	50-29-3	µg/kg	c		1,700	4.2	4	SW8081A	**2.0**	**0.30**	**0.15**
Total DDTs	NA	µg/kg	c		NS	5.3	5	SW8081A	**2.0**	**0.30**	**0.15**
Dieldrin	60-57-1	µg/kg	c		30	1.9	2	SW8081A	**2.0**	**0.30**	**0.12**
Endosulfan I	959-98-8	µg/kg	nc		370,000	0.010	0	SW8081A	**1.0**	**0.30**	**0.10**
Endosulfan II	33213-65-9	µg/kg	nc		370,000	0.010	0	SW8081A	**2.0**	**0.30**	**0.17**
Endosulfan sulfate	1031-07-8	µg/kg	nc		370,000	NS	370,000	SW8081A	2.0	0.30	0.19
Endrin	72-20-8	µg/kg	nc	9,000	18,000	2.2	2	SW8081A	2.0	0.30	0.16
Endrin aldehyde	7421-93-4	µg/kg	nc	19,000	NS	NS	19,000	SW8081A	2.0	0.30	0.20
Endrin ketone	53494-70-5	µg/kg	nc	19,000	NS	NS	19,000	SW8081A	2.0	0.50	0.26
Heptachlor	76-44-8	µg/kg	c		110	0.70	1	SW8081A	**1.0**	0.50	0.46
Heptachlor epoxide	1024-57-3	µg/kg	c		53	2.5	2	SW8081A	1.0	0.30	0.0030
Methoxychlor	72-43-5	µg/kg	nc		310,000	19	19	SW8081A	10	0.30	0.26
Toxaphene	8001-35-2	µg/kg	c		440	0.10	0	SW8081A	**100**	**50**	**10**
Polychlorinated Biphenyls (PCBs)											
Aroclor 1016	12674-11-2	µg/kg	nc		3,900	NS	3,900	SW8082	10	5.0	3.2
Aroclor 1221	11104-28-2	µg/kg	c		140	NS	140	SW8082	10	8.0	8.0
Aroclor 1232	11141-16-5	µg/kg	c		140	NS	140	SW8082	10	8.0	7.0
Aroclor 1242	53469-21-9	µg/kg	c		220	NS	220	SW8082	10	5.0	2.1
Aroclor 1248	12672-79-6	µg/kg	c		220	NS	220	SW8082	10	3.0	3.0
Aroclor 1254	11097-69-1	µg/kg	c		220	60	60	SW8082	10	5.0	2.1
Aroclor 1260	11096-82-5	µg/kg	c		220	NS	220	SW8082	10	5.0	3.0
Total PCBs	1336-36-3	µg/kg	c		220	60	60	SW8082	**10**	**8.0**	**8.0**
Total Metals											
Aluminum	7429-90-5	mg/kg	nc	65,000	77,000	25,500	25,500	SW6010B	50	10	8.9

TABLE A-4. REFERENCE LIMITS AND PROJECT ACTION LIMITS FOR SEDIMENT
FALCON REFINERY SUPERFUND SITE

Analyte	CASRN	Units	c/nc	TCEQ TRRP Residential[1] TotSoil Comb	USEPA Regional Screening Level[2]	Protection of Benthic Invertebrates Screening Level[3]	PAL[4]	Achievable Laboratory Limits (TestAmerica Tacoma)			
								Analytical Method	LOQ	LOD	DL
Antimony	7440-36-0	mg/kg	nc	15	31	3.0	3	SW6020	0.20	0.080	0.042
Arsenic	7440-38-2	mg/kg	c	24	0.39	9.8	0	SW6020	**0.50**	**0.40**	0.18
Barium	7440-39-3	mg/kg	nc	8,100	15,000	NS	8,100	SW6020	0.20	0.040	0.030
Beryllium	7440-41-7	mg/kg	c	38	160	NS	38	SW6020	0.20	0.040	0.022
Cadmium	7440-43-9	mg/kg	c	52	70	0.99	1	SW6020	0.20	0.020	0.0080
Calcium	7440-70-2	mg/kg	-	1,000,000	NS	NS	1,000,000	SW6010B	55	7.5	5.2
Chromium	7440-47-3	mg/kg	nc	Cr III = 33,000 Cr VI = 120 Cr Total =33,000	Cr VI =0.29	Cr III or IV = 43.4	0.29	SW6020	0.20	0.15	0.11
Cobalt	7440-48-4	mg/kg	nc	21	23	50	21	SW6020	0.20	0.040	0.019
Copper	7440-50-8	mg/kg	nc	550	3,100	32	32	SW6020	0.40	0.20	0.098
Iron	7439-89-6	mg/kg	nc	1,000,000	55,000	20,000	20,000	SW6010B	10	5.00	3.60
Lead	7439-92-1	mg/kg	-	500	400	36	36	SW6020	0.20	0.020	0.013
Magnesium	7439-95-4	mg/kg	-	1,000,000	NS	NS	1,000,000	SW6010B	55	4.0	3.2
Manganese	7439-96-5	mg/kg	nc	3,700	1,800	460	460	SW6020	0.50	0.20	0.17
Mercury	7439-97-6	mg/kg	nc	3.6	10	0.18	0	SW7471A	0.020	0.010	0.0063
Nickel	7440-02-0	mg/kg	nc	840	1,500	23	23	SW6020	0.50	0.25	0.071
Potassium	7440-09-7	mg/kg	-	1,000,000	NS	NS	1,000,000	SW6010B	165	20	16
Selenium	7782-49-2	mg/kg	nc	310	390	NS	310	SW6020	0.70	0.40	0.20
Silver	7440-22-4	mg/kg	nc	97	390	0.50	1	SW6020	0.20	0.020	0.012
Sodium	7440-23-5	mg/kg	-	1,000,000	NS	NS	1,000,000	SW6010B	100	15	15
Thallium	7440-28-0	mg/kg	nc	6.3	0.78	NS	1	SW6020	0.50	0.26	0.13
Vanadium	7440-62-2	mg/kg	nc	76	390	NS	76	SW6020	0.70	0.50	0.47
Zinc	7440-66-6	mg/kg	nc	9,900	23,000	121	121	SW6020	2.0	1.5	1.1

Notes:

c - carcinogenic; nc - noncarcinogenic

TestAmerica analytes shown in bold and highlight have a PAL lower than or equal to the LOQ/LOD/DL.

[1] TCEQ TRRP Table 1 Tier 1 Residential Soil PCLs, June 29, 2012

[2] USEPA May 2012 RSLs as presented at the following website at http://www.epa.gov/region9/superfund/prg/.

[3] Benthic protection based on the NOAA SQuIRTs values listed in Buchman (2008), consensus-based unless not available, otherwise the lowest of listed screening values are presented.

[4] PALs refer to the lowest applicable screening level.

µg/kg = microgram(s) per kilogram
mg/kg = milligram(s) per kilogram.
TCEQ = Texas Commission on Environmental Quality
ADEC = Alaska Department of Environmental Conservation
CASRN = Chemical Abstracts Service Registry Number
DL = detection limit
HQ - hazard quotient
LOD = limit of detection
LOQ = limit of quantitation
NA = not applicable
NOAA = National Oceanic and Atmospheric Administration
NS = not specified
PAL = project action limit
PQL = practical quantitation limit
SIM = selected ion monitoring
SQuIRT = Screening Quick Reference Tables
USEPA = U.S. Environmental Protection Agency

TABLE A-5 REFERENCE LIMITS FOR CONTAMINANTS IN FISH TISSUE
FALCON REFINING SUPERFUND SITE

Analyte	CASRN	Units	Safety Levels
Organochlorine Pesticides			
Aldrin	309-00-2	ppm	0.3
alpha-BHC	319-84-6	ppm	
beta-BHC	319-85-7	ppm	
delta-BHC	319-86-8	ppm	
gamma-BHC (Lindane)	58-89-9	ppm	
alpha-Chlordane	5103-71-9	ppm	0.3
gamma-Chlordane	5103-74-2	ppm	0.3
4,4-DDD	72-54-8	ppm	
4,4-DDE	72-55-9	ppm	5
4,4-DDT	50-29-3	ppm	5
Total DDTs	NA	ppm	
Dieldrin	60-57-1	ppm	0.3
Endosulfan I	959-98-8	ppm	
Endosulfan II	33213-65-9	ppm	
Endosulfan sulfate	1031-07-8	ppm	
Endrin	72-20-8	ppm	
Endrin aldehyde	7421-93-4	ppm	
Endrin ketone	53494-70-5	ppm	
Heptachlor	76-44-8	ppm	0.3
Heptachlor epoxide	1024-57-3	ppm	0.3
Methoxychlor	72-43-5	ppm	
Toxaphene	8001-35-2	ppm	
Polychlorinated Biphenyls (PCBs)			
Aroclor 1016	12674-11-2	ppm	
Aroclor 1221	11104-28-2	ppm	
Aroclor 1232	11141-16-5	ppm	
Aroclor 1242	53469-21-9	ppm	
Aroclor 1248	12672-79-6	ppm	
Aroclor 1254	11097-69-1	ppm	
Aroclor 1260	11096-82-5	ppm	
Total PCBs	1336-36-3	ppm	2

Notes:
Source = Safety Levels for Fish and Fishery Products Hazards and Controls
Guidance = Fourth Edition (United States Food and Drug Administration 2011)
CASRN = Chemical Abstracts Service Registry Number
ppm = parts per million

Appendix B

APPENDIX B
INDEX OF VSP REPORTS
FALCON REFINERY
INGLESIDE, TEXAS

Report Number	Area Of Concern	Media	Benchmark
1	AOC-1	Surface Soil	Human Health
2	AOC-1	Surface Soil	Ecological
3	AOC-1	Subsurface Soil	Human Health
4	AOC-1	Subsurface Soil	Ecological
5	AOC-1	Groundwater	Human Health
6	AOC-3	Surface Soil	Human Health
7	AOC-3	Surface Soil	Ecological
8	AOC-3	Subsurface Soil	Human Health
9	AOC-3	Subsurface Soil	Ecological
10	AOC-3	Surface Water	Human Health
11	AOC-3	Surface Water	Ecological
12	AOC-3	Sediment	Human Health
13	AOC-3	Sediment	Ecological

Appendix B

VSP Reports of Calculated Minimum Sample Quantity

Report 1

Area of Concern – 1

Minimum Sample Quantity Calculation for Surface Soil using Human Health Benchmarks

Systematic sampling locations for comparing a mean with a fixed threshold (parametric)

Summary
This report summarizes the sampling design, associated statistical assumptions, as well as general guidelines for conducting post-sampling data analysis. Sampling plan components presented here include how many sampling locations to choose and where within the sampling area to collect those samples. The type of medium to sample (i.e., soil, groundwater, etc.) and how to analyze the samples (in-situ, fixed laboratory, etc.) are addressed in other sections of the sampling plan.

The following table summarizes the sampling design. A figure that shows sampling locations in the field and a table that lists sampling location coordinates are also provided below.

SUMMARY OF SAMPLING DESIGN	
Primary Objective of Design	Compare a site mean to a fixed threshold
Type of Sampling Design	Parametric
Sample Placement (Location) in the Field	Systematic with a random start location
Working (Null) Hypothesis	The mean value at the site exceeds the threshold
Formula for calculating number of sampling locations	Student's t-test
Calculated total number of samples	36
Number of samples on map [a]	36
Number of selected sample areas [b]	3
Specified sampling area [c]	2024225.46 ft^2
Size of grid / Area of grid cell [d]	254.808 feet / 56228.5 ft^2
Grid pattern	Triangular
Total cost of sampling [e]	$19,000.00

[a] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.
[b] The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.
[c] The sampling area is the total surface area of the selected colored sample areas on the map of the site.
[d] Size of grid / Area of grid cell gives the linear and square dimensions of the grid used to systematically place samples.
[e] Including measurement analyses and fixed overhead costs. See the Cost of Sampling section for an explanation of the costs presented here.

Area: AOC-1N					
X Coord	Y Coord	Label	Value	Type	Historical
1410592.8661	17204383.3090			Systematic	
1410847.6740	17204383.3090			Systematic	
1411102.4819	17204383.3090			Systematic	
1410720.2701	17204603.9791			Systematic	
1410975.0779	17204603.9791			Systematic	
1411229.8858	17204603.9791			Systematic	
1410847.6740	17204824.6492			Systematic	

Area: AOC-1S (1)					
X Coord	Y Coord	Label	Value	Type	Historical
1411072.0461	17202146.2766			Systematic	
1411326.8540	17202146.2766			Systematic	
1411199.4501	17202366.9467			Systematic	
1411454.2579	17202366.9467			Systematic	
1410817.2382	17202587.6168			Systematic	
1411072.0461	17202587.6168			Systematic	
1411326.8540	17202587.6168			Systematic	
1411581.6619	17202587.6168			Systematic	
1410944.6422	17202808.2869			Systematic	
1411199.4501	17202808.2869			Systematic	
1411454.2579	17202808.2869			Systematic	
1411709.0658	17202808.2869			Systematic	

1411072.0461	17203028.9571			Systematic	
1411326.8540	17203028.9571			Systematic	
1411581.6619	17203028.9571			Systematic	
1411836.4698	17203028.9571			Systematic	
1410689.8343	17203249.6272			Systematic	
1410944.6422	17203249.6272			Systematic	
1411199.4501	17203249.6272			Systematic	
1411454.2579	17203249.6272			Systematic	
1411709.0658	17203249.6272			Systematic	
1411963.8737	17203249.6272			Systematic	
1410817.2382	17203470.2973			Systematic	
1411072.0461	17203470.2973			Systematic	
1411326.8540	17203470.2973			Systematic	
1411581.6619	17203470.2973			Systematic	
1410944.6422	17203690.9674			Systematic	
1411199.4501	17203690.9674			Systematic	

Area: AOC-1S (2)					
X Coord	**Y Coord**	**Label**	**Value**	**Type**	**Historical**
1410607.3154	17202084.2956			Systematic	

Primary Sampling Objective
The primary purpose of sampling at this site is to compare a mean value of a site with a fixed threshold. The working hypothesis (or 'null' hypothesis) is that the mean value at the site is equal to or exceeds the threshold. The alternative hypothesis is that the mean value is less than the threshold. VSP calculates the number of samples required to reject the null hypothesis in favor of the alternative hypothesis, given a selected sampling approach and inputs to the associated equation.

Selected Sampling Approach
A parametric systematic sampling approach with a random start was used to determine the number of samples and to specify sampling locations. A parametric formula was chosen because the conceptual model and historical information (e.g., historical data from this site or a very similar site) indicate that parametric assumptions are reasonable. These assumptions will be examined in post-sampling data analysis.

Both parametric and non-parametric approaches rely on assumptions about the population. However, non-parametric approaches typically require fewer assumptions and allow for more uncertainty about the statistical distribution of values at the site. The trade-off is that if the parametric assumptions are valid, the required number of samples is usually less than the number of samples required by non-parametric approaches.

Locating the sample points over a systematic grid with a random start ensures spatial coverage of the site. Statistical analyses of systematically collected data are valid if a random start to the grid is used. One disadvantage of systematically collected samples is that spatial variability or patterns may not be discovered if the grid spacing is large relative to the spatial patterns.

Number of Total Samples: Calculation Equation and Inputs
The equation used to calculate the number of samples is based on a Student's t-test. For this site, the null hypothesis is rejected in favor of the alternative hypothesis if the sample mean is sufficiently smaller than the threshold. The number of samples to collect is calculated so that 1) there will be a high probability ($1-\beta$) of rejecting the null hypothesis if the alternative hypothesis is true and 2) a low probability (α) of rejecting the null hypothesis if the null hypothesis is true.

The formula used to calculate the number of samples is:

$$n = \frac{S^2}{\Delta^2}\left(Z_{1-\alpha} + Z_{1-\beta}\right)^2 + 0.5Z_{1-\alpha}^2$$

where

n	is the number of samples,
S	is the estimated standard deviation of the measured values including analytical error,
Δ	is the width of the gray region,
α	is the acceptable probability of incorrectly concluding the site mean is less than the threshold,
β	is the acceptable probability of incorrectly concluding the site mean exceeds the threshold,
$Z_{1-\alpha}$	is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\alpha}$ is 1-α,
$Z_{1-\beta}$	is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\beta}$ is 1-β.

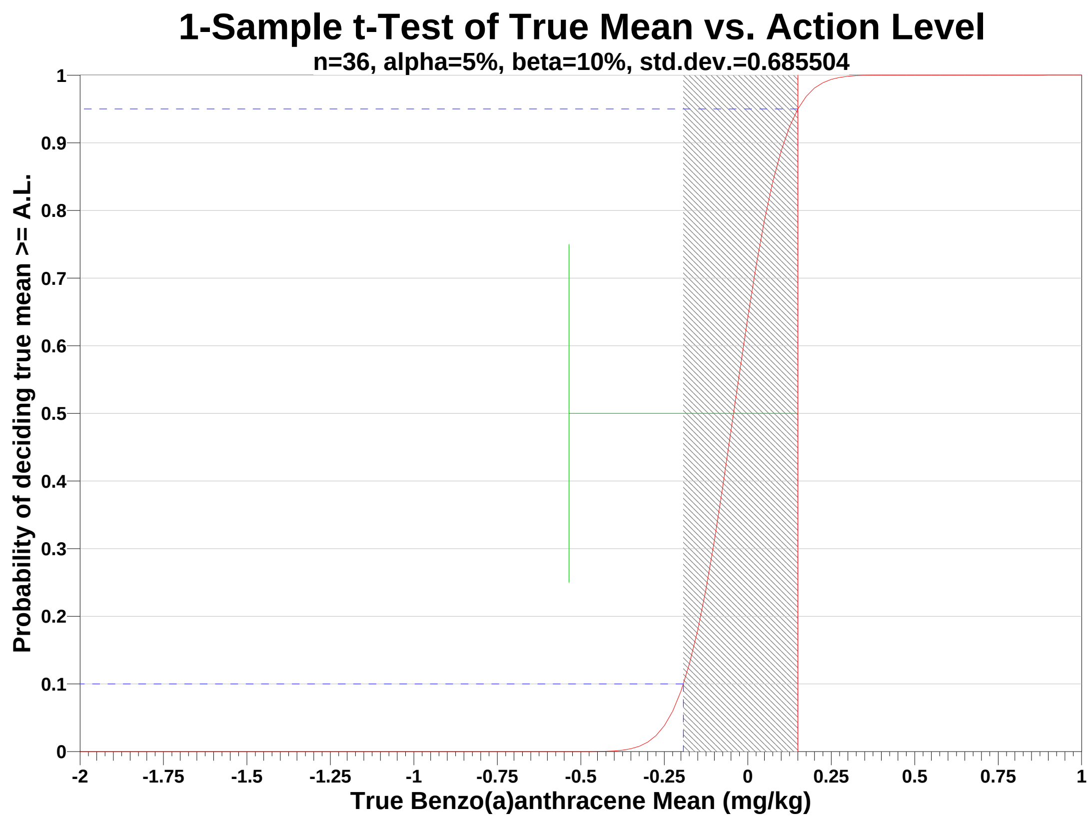
The values of these inputs that result in the calculated number of sampling locations are:

Analyte	**n**	**Parameter**					
		S	Δ	α	β	$Z_{1-\alpha}$ [a]	$Z_{1-\beta}$ [b]
Benzo(a)anthracene	36	0.685504 mg/kg	0.342752 mg/kg	0.05	0.1	1.64485	1.28155

[a] This value is automatically calculated by VSP based upon the user defined value of α.
[b] This value is automatically calculated by VSP based upon the user defined value of β.

The following figure is a performance goal diagram, described in EPA's QA/G-4 guidance (EPA, 2000). It shows the probability of concluding the sample area is dirty on the vertical axis versus a range of possible true mean values for the site on the horizontal axis. This graph contains all of the inputs to the number of samples equation and pictorially represents the calculation.

The red vertical line is shown at the threshold (action limit) on the horizontal axis. The width of the gray shaded area is equal to Δ; the upper horizontal dashed blue line is positioned at 1-α on the vertical axis; the lower horizontal dashed blue line is positioned at β on the vertical axis. The vertical green line is positioned at one standard deviation below the threshold. The shape of the red curve corresponds to the estimates of variability. The calculated number of samples results in the curve that passes through the lower bound of Δ at β and the upper bound of Δ at 1-α. If any of the inputs change, the number of samples that result in the correct curve changes.



Statistical Assumptions

The assumptions associated with the formulas for computing the number of samples are:

1. the sample mean is normally distributed (this happens if the data are roughly symmetric or the sample size is more than 30; for extremely skewed data sets, additional samples may be required for the sample mean to be normally distributed),
2. the variance estimate, S^2, is reasonable and representative of the population being sampled,
3. the population values are not spatially or temporally correlated, and
4. the sampling locations will be selected probabilistically.

The first three assumptions will be assessed in a post data collection analysis. The last assumption is valid because the gridded sample locations were selected based on a random start.

Sensitivity Analysis

The sensitivity of the calculation of number of samples was explored by varying the standard deviation, lower bound of gray region (% of action level), beta (%), probability of mistakenly concluding that μ > action level and alpha (%), probability of mistakenly concluding that μ < action level. The following table shows the results of this analysis.

Number of Samples							
AL=0.15		**α=5**		**α=10**		**α=15**	
		s=1.37101	**s=0.685504**	**s=1.37101**	**s=0.685504**	**s=1.37101**	**s=0.685504**
LBGR=90	**β=5**	90411	22604	71544	17887	60061	15016
	β=10	71545	17888	54883	13722	44888	11223
	β=15	60062	15017	44888	11223	35897	8975
LBGR=80	**β=5**	22604	5652	17887	4473	15016	3755
	β=10	17888	4473	13722	3431	11223	2806
	β=15	15017	3756	11223	2807	8975	2245
LBGR=70	**β=5**	10047	2513	7951	1989	6674	1669

	β=10	7951	1989	6099	1526	4988	1248
	β=15	6675	1670	4989	1248	3989	998

s = Standard Deviation
LBGR = Lower Bound of Gray Region (% of Action Level)
β = Beta (%), Probability of mistakenly concluding that μ > action level
α = Alpha (%), Probability of mistakenly concluding that μ < action level
AL = Action Level (Threshold)

Cost of Sampling
The total cost of the completed sampling program depends on several cost inputs, some of which are fixed, and others that are based on the number of samples collected and measured. Based on the numbers of samples determined above, the estimated total cost of sampling and analysis at this site is $19,000.00, which averages out to a per sample cost of $527.78. The following table summarizes the inputs and resulting cost estimates.

COST INFORMATION			
Cost Details	**Per Analysis**	**Per Sample**	**36 Samples**
Field collection costs		$100.00	$3,600.00
Analytical costs	$400.00	$400.00	$14,400.00
Sum of Field & Analytical costs		**$500.00**	**$18,000.00**
Fixed planning and validation costs			$1,000.00
Total cost			**$19,000.00**

Data Analysis for Benzo(a)anthracene
The following data points were entered by the user for analysis.

Benzo(a)anthracene (mg/kg)										
Rank	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0	0.034	0.035	0.036	0.036	0.036	0.0365	0.037	0.037	0.037	0.037
10	0.0375	0.0375	0.0378	0.038	0.038	0.038	0.0385	0.0388	0.039	0.039
20	0.0395	0.04	0.04	0.04	0.0405	0.041	0.041	0.042	0.042	0.0425
30	0.055	0.121	0.142	0.355	0.36	0.37	0.39	0.398	0.648	0.72
40	3.97									

SUMMARY STATISTICS for Benzo(a)anthracene	
n	41
Min	0.034
Max	3.97
Range	3.936
Mean	0.21173
Median	0.0395
Variance	0.39116
StdDev	0.62543
Std Error	0.097675
Skewness	5.711

Interquartile Range				0.05075				
Percentiles								
1%	**5%**	**10%**	**25%**	**50%**	**75%**	**90%**	**95%**	**99%**
0.034	0.0351	0.036	0.03725	0.0395	0.088	0.3964	0.7128	3.97

Outlier Test
Rosner's test for multiple outliers was performed to test whether the most extreme value is a statistical outlier. The test was conducted at the 5% significance level.

Data should not be excluded from analysis solely on the basis of the results of this or any other statistical test. If any values are flagged as possible outliers, further investigation is recommended to determine whether there is a plausible explanation that justifies removing or replacing them.

In using Rosner's test to detect up to 1 outlier, a test statistic R_1 is calculated, and compared with a critical value C_1 to test the hypothesis that there is one outlier in the data.

ROSNER'S OUTLIER TEST for Benzo(a)anthracene			
k	**Test Statistic R_k**	**5% Critical Value C_k**	**Significant?**
1	6.009	3.05	Yes

The test statistic 6.009 exceeded the corresponding critical value, therefore that test is significant and we conclude that the most extreme value is an outlier at the 5% significance level.

SUSPECTED OUTLIERS for Benzo(a)anthracene	
1	3.97

A normal distribution test indicated that the data do not appear to be normally distributed, so further investigation is recommended before using the results of this test. Because Rosner's test can be used only when the data without the suspected outlier are approximately normally distributed, a Shapiro-Wilk test for normality was performed at a 5% significance level.

NORMAL DISTRIBUTION TEST (excluding outliers)	
Shapiro-Wilk Test Statistic	0.5398
Shapiro-Wilk 5% Critical Value	0.94

The calculated Shapiro-Wilk test statistic is less than the 5% Shapiro-Wilk critical value, so the test rejects the hypothesis that the data are normal and concludes that the data, excluding the most extreme value, do not appear to follow a normal distribution at the 5% level of significance. Rosner's test may not be appropriate if the assumption of normally distributed data is not justified for this data set. Examine the Q-Q plot displayed below to further assess the normality of the data.

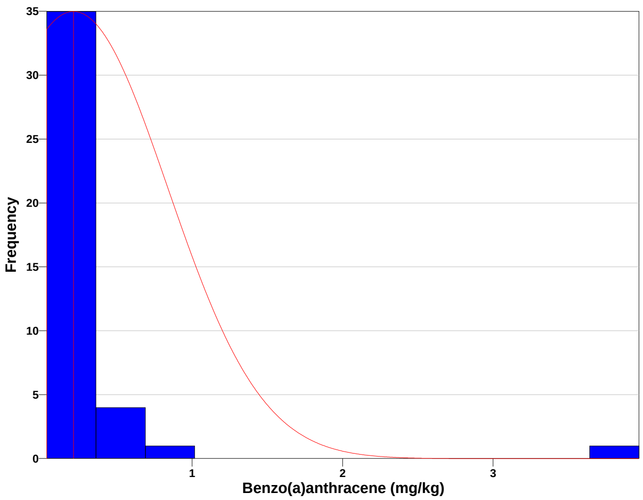
Data Plots for Benzo(a)anthracene
Graphical displays of the data are shown below.

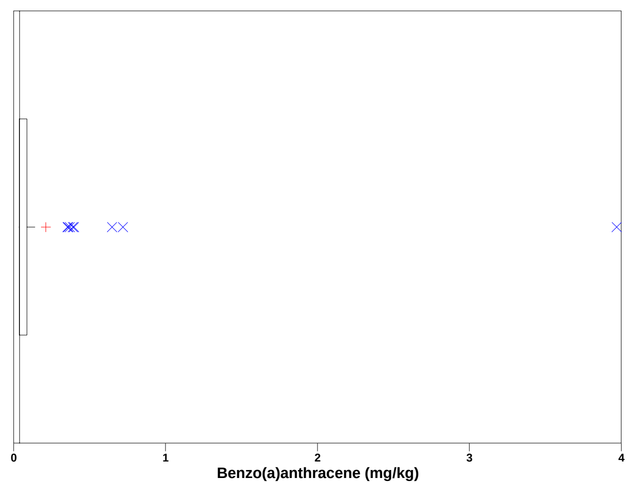
The Histogram is a plot of the fraction of the n observed data that fall within specified data “bins.” A histogram is generated by dividing the x axis (range of the observed data values) into "bins" and displaying the number of data in each bin as the height of a bar for the bin. The area of the bar is the fraction of the n data values that lie within the bin. The sum of the fractions for all bins equals one. A histogram is used to assess how the n data are distributed (spread) over their range of values. If the histogram is more or less symmetric and bell shaped, then the data may be normally distributed.

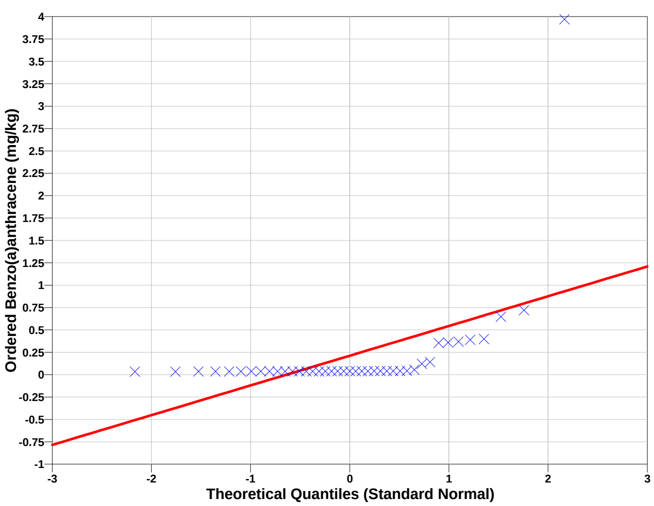
The Box and Whiskers plot is composed of a central box divided by a line, and with two lines extending out from the box, called the "whiskers". The line through the box is drawn at the median of the n data observed. The two ends of the box represent the 25^{th} and 75^{th} percentiles of the n data values, which are also called the lower and upper quartiles, respectively, of the data set. The sample mean (mean of the n data) is shown as a "+" sign. The upper whisker extends to

the largest data value that is less than the upper quartile plus 1.5 times the interquartile range (upper quartile minus the lower quartile). The lower whisker extends to the smallest data value that is greater than the lower quartile minus 1.5 times the interquartile range. Extreme data values (greater or smaller than the ends of the whiskers) are plotted individually as blue Xs. A Box and Whiskers plot is used to assess the symmetry of the distribution of the data set. If the distribution is symmetrical, the box is divided into two equal halves by the median, the whiskers will be the same length, and the number of extreme data points will be distributed equally on either end of the plot.

The Q-Q plot graphs the quantiles of a set of n data against the quantiles of a specific distribution. We show here only the Q-Q plot for an assumed normal distribution. The p^{th} quantile of a distribution of data is the data value, x_n, for which a fraction p of the distribution is less than x_n. If the data plotted on the normal distribution Q-Q plot closely follow a straight line, even at the ends of the line, then the data may be assumed to be normally distributed. If the data points deviate substantially from a linear line, then the data are not normally distributed.







□□□□□For more information on these plots consult Guidance for Data Quality Assessment, EPA QA/G-9, pgs 2.3-1 through 2.3-12. (http://www.epa.gov/quality/qa-docs.html).

Tests for Benzo(a)anthracene

A goodness-of-fit test was performed to test whether the data set had been drawn from an underlying normal distribution. The Shapiro-Wilk (SW) test was used to test the null hypothesis that the data are normally distributed. The test was conducted at the 5% significance level, i.e., the probability the test incorrectly rejects the null hypothesis was set at 0.05.

NORMAL DISTRIBUTION TEST	
Shapiro-Wilk Test Statistic	0.3091

Shapiro-Wilk 5% Critical Value	0.941

The calculated SW test statistic is less than the 5% Shapiro-Wilk critical value, so we can reject the hypothesis that the data are normal, or in other words the data do not appear to follow a normal distribution at the 5% level of significance. The Q-Q plot displayed above should be used to further assess the normality of the data.

Upper Confidence Limit on the True Mean
Two methods were used to compute the upper confidence limit (UCL) on the mean. The first is a parametric method that assumes a normal distribution. The second is the Chebyshev method, which requires no distributional assumption.

UCLs ON THE MEAN	
95% Parametric UCL	0.3762
95% Non-Parametric (Chebyshev) UCL	0.63749

Because the data do not appear to be normally distributed according to the goodness-of-fit test performed above, the non-parametric UCL (0.6375) may be a more accurate upper confidence limit on the true mean.

One-Sample t-Test
A one-sample t-test was performed to compare the sample mean to the action level. The null hypothesis used is that the true mean equals or exceeds the action level (AL). The t-test was conducted at the 5% significance level. The sample value *t* was computed using the following equation:

$$t = \frac{\bar{x} - AL}{SE}$$

where
x is the sample mean of the n=41 data,
AL is the action level or threshold (0.15),
SE is the standard error = (standard deviation) / (square root of n).

This *t* was then compared with the critical value $t_{0.95}$, where $t_{0.95}$ is the value of the t distribution with n-1=40 degrees of freedom for which the proportion of the distribution to the left of $t_{0.95}$ is 0.95. The null hypothesis will be rejected if $t < -t_{0.95}$.

ONE-SAMPLE t-TEST		
t-statistic	**Critical Value $t_{0.95}$**	**Null Hypothesis**
0.63203	1.6839	Cannot Reject

The test did not reject the null hypothesis that the mean value at the site exceeds the threshold, therefore conclude the true mean exceeds the threshold.

Because the data do not appear to be normally distributed, the MARSSIM Sign Test might be preferred over the One Sample t-Test. The following table represents the results of the MARSSIM Sign Test using the current data:

MARSSIM Sign Test		
Test Statistic (S+)	**95% Critical Value**	**Null Hypothesis**
33	26	Reject

Appendix B

VSP Reports of Calculated Minimum Sample Quantity

Report 2

Area of Concern – 1

Minimum Sample Quantity Calculation for Surface Soil using Ecological Benchmarks

Systematic sampling locations for comparing a mean with a fixed threshold (parametric)

Summary
This report summarizes the sampling design, associated statistical assumptions, as well as general guidelines for conducting post-sampling data analysis. Sampling plan components presented here include how many sampling locations to choose and where within the sampling area to collect those samples. The type of medium to sample (i.e., soil, groundwater, etc.) and how to analyze the samples (in-situ, fixed laboratory, etc.) are addressed in other sections of the sampling plan.

The following table summarizes the sampling design. A figure that shows sampling locations in the field and a table that lists sampling location coordinates are also provided below.

SUMMARY OF SAMPLING DESIGN	
Primary Objective of Design	Compare a site mean to a fixed threshold
Type of Sampling Design	Parametric
Sample Placement (Location) in the Field	Systematic with a random start location
Working (Null) Hypothesis	The mean value at the site exceeds the threshold
Formula for calculating number of sampling locations	Student's t-test
Calculated total number of samples	36
Number of samples on map [a]	36
Number of selected sample areas [b]	3
Specified sampling area [c]	2024225.46 ft^2
Size of grid / Area of grid cell [d]	254.808 feet / 56228.5 ft^2
Grid pattern	Triangular
Total cost of sampling [e]	$19,000.00

[a] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.
[b] The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.
[c] The sampling area is the total surface area of the selected colored sample areas on the map of the site.
[d] Size of grid / Area of grid cell gives the linear and square dimensions of the grid used to systematically place samples.
[e] Including measurement analyses and fixed overhead costs. See the Cost of Sampling section for an explanation of the costs presented here.

Area: AOC-1N					
X Coord	Y Coord	Label	Value	Type	Historical
1410600.7500	17204387.8224			Systematic	
1410855.5579	17204387.8224			Systematic	
1411110.3658	17204387.8224			Systematic	
1410728.1540	17204608.4925			Systematic	
1410982.9618	17204608.4925			Systematic	
1411237.7697	17204608.4925			Systematic	
1410855.5579	17204829.1626			Systematic	

Area: AOC-1S (1)					
X Coord	Y Coord	Label	Value	Type	Historical
1410996.5304	17202151.6740			Systematic	
1411123.9343	17202372.3441			Systematic	
1411378.7422	17202372.3441			Systematic	
1410996.5304	17202593.0142			Systematic	
1411251.3383	17202593.0142			Systematic	
1411506.1462	17202593.0142			Systematic	
1410869.1264	17202813.6843			Systematic	
1411123.9343	17202813.6843			Systematic	
1411378.7422	17202813.6843			Systematic	
1411633.5501	17202813.6843			Systematic	
1410996.5304	17203034.3544			Systematic	
1411251.3383	17203034.3544			Systematic	

1411506.1462	17203034.3544			Systematic	
1411760.9541	17203034.3544			Systematic	
1410614.3185	17203255.0245			Systematic	
1410869.1264	17203255.0245			Systematic	
1411123.9343	17203255.0245			Systematic	
1411378.7422	17203255.0245			Systematic	
1411633.5501	17203255.0245			Systematic	
1411888.3580	17203255.0245			Systematic	
1410741.7225	17203475.6946			Systematic	
1410996.5304	17203475.6946			Systematic	
1411251.3383	17203475.6946			Systematic	
1411506.1462	17203475.6946			Systematic	
1410869.1264	17203696.3647			Systematic	
1411123.9343	17203696.3647			Systematic	
1411378.7422	17203696.3647			Systematic	
1410996.5304	17203917.0348			Systematic	

Area: AOC-1S (2)					
X Coord	**Y Coord**	**Label**	**Value**	**Type**	**Historical**
1410608.7711	17202087.6654			Systematic	

Primary Sampling Objective
The primary purpose of sampling at this site is to compare a mean value of a site with a fixed threshold. The working hypothesis (or 'null' hypothesis) is that the mean value at the site is equal to or exceeds the threshold. The alternative hypothesis is that the mean value is less than the threshold. VSP calculates the number of samples required to reject the null hypothesis in favor of the alternative hypothesis, given a selected sampling approach and inputs to the associated equation.

Selected Sampling Approach
A parametric systematic sampling approach with a random start was used to determine the number of samples and to specify sampling locations. A parametric formula was chosen because the conceptual model and historical information (e.g., historical data from this site or a very similar site) indicate that parametric assumptions are reasonable. These assumptions will be examined in post-sampling data analysis.

Both parametric and non-parametric approaches rely on assumptions about the population. However, non-parametric approaches typically require fewer assumptions and allow for more uncertainty about the statistical distribution of values at the site. The trade-off is that if the parametric assumptions are valid, the required number of samples is usually less than the number of samples required by non-parametric approaches.

Locating the sample points over a systematic grid with a random start ensures spatial coverage of the site. Statistical analyses of systematically collected data are valid if a random start to the grid is used. One disadvantage of systematically collected samples is that spatial variability or patterns may not be discovered if the grid spacing is large relative to the spatial patterns.

Number of Total Samples: Calculation Equation and Inputs
The equation used to calculate the number of samples is based on a Student's t-test. For this site, the null hypothesis is rejected in favor of the alternative hypothesis if the sample mean is sufficiently smaller than the threshold. The number of samples to collect is calculated so that 1) there will be a high probability ($1-\beta$) of rejecting the null hypothesis if the alternative hypothesis is true and 2) a low probability (α) of rejecting the null hypothesis if the null hypothesis is true.

The formula used to calculate the number of samples is:

$$n = \frac{S^2}{\Delta^2}\left(Z_{1-\alpha} + Z_{1-\beta}\right)^2 + 0.5 Z_{1-\alpha}^2$$

where

n is the number of samples,
S is the estimated standard deviation of the measured values including analytical error,
Δ is the width of the gray region,
α is the acceptable probability of incorrectly concluding the site mean is less than the threshold,
β is the acceptable probability of incorrectly concluding the site mean exceeds the threshold,
$Z_{1-\alpha}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\alpha}$ is $1-\alpha$,
$Z_{1-\beta}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\beta}$ is $1-\beta$.

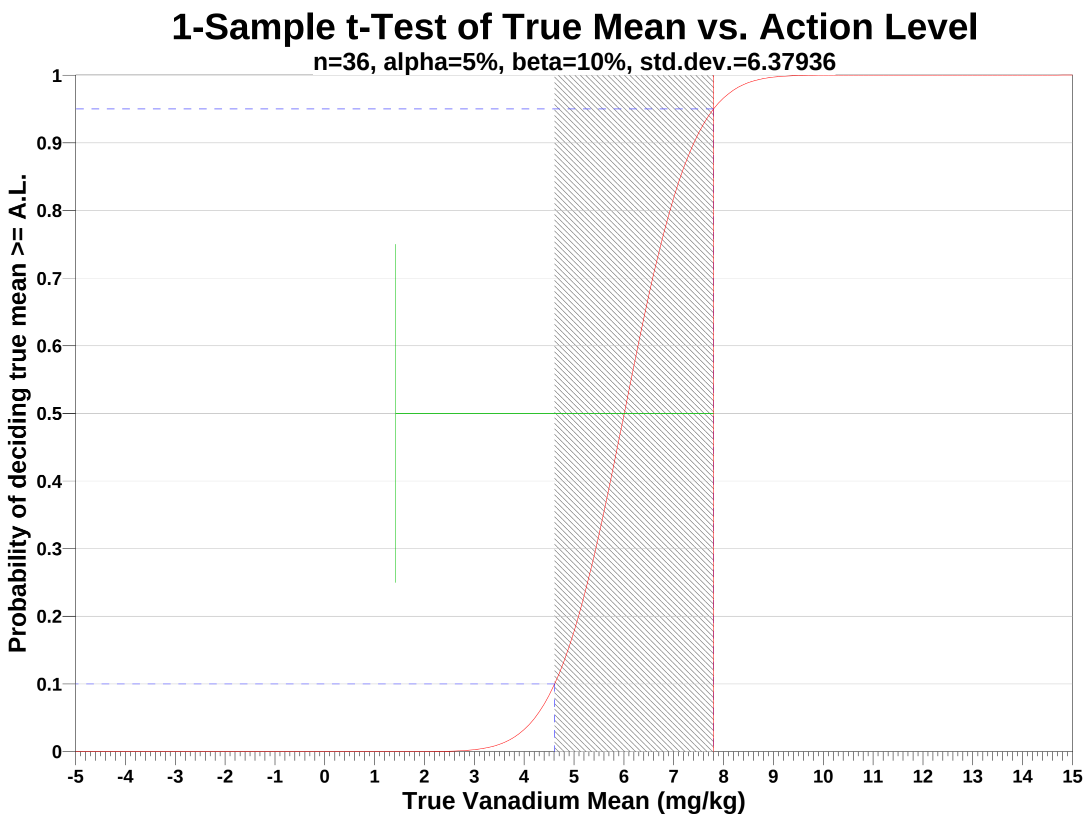
The values of these inputs that result in the calculated number of sampling locations are:

Analyte	n	Parameter					
		S	Δ	α	β	$Z_{1-\alpha}$ [a]	$Z_{1-\beta}$ [b]
Vanadium	36	6.37936 mg/kg	3.18968 mg/kg	0.05	0.1	1.64485	1.28155

[a] This value is automatically calculated by VSP based upon the user defined value of α.
[b] This value is automatically calculated by VSP based upon the user defined value of β.

The following figure is a performance goal diagram, described in EPA's QA/G-4 guidance (EPA, 2000). It shows the probability of concluding the sample area is dirty on the vertical axis versus a range of possible true mean values for the site on the horizontal axis. This graph contains all of the inputs to the number of samples equation and pictorially represents the calculation.

The red vertical line is shown at the threshold (action limit) on the horizontal axis. The width of the gray shaded area is equal to Δ; the upper horizontal dashed blue line is positioned at $1-\alpha$ on the vertical axis; the lower horizontal dashed blue line is positioned at β on the vertical axis. The vertical green line is positioned at one standard deviation below the threshold. The shape of the red curve corresponds to the estimates of variability. The calculated number of samples results in the curve that passes through the lower bound of Δ at β and the upper bound of Δ at $1-\alpha$. If any of the inputs change, the number of samples that result in the correct curve changes.



Statistical Assumptions

The assumptions associated with the formulas for computing the number of samples are:

1. the sample mean is normally distributed (this happens if the data are roughly symmetric or the sample size is more than 30; for extremely skewed data sets, additional samples may be required for the sample mean to be normally distributed),
2. the variance estimate, S^2, is reasonable and representative of the population being sampled,
3. the population values are not spatially or temporally correlated, and
4. the sampling locations will be selected probabilistically.

The first three assumptions will be assessed in a post data collection analysis. The last assumption is valid because the gridded sample locations were selected based on a random start.

Sensitivity Analysis

The sensitivity of the calculation of number of samples was explored by varying the standard deviation, lower bound of gray region (% of action level), beta (%), probability of mistakenly concluding that μ > action level and alpha (%), probability of mistakenly concluding that μ < action level. The following table shows the results of this analysis.

Number of Samples							
AL=7.8		α=5		α=10		α=15	
		s=12.7587	s=6.37936	s=12.7587	s=6.37936	s=12.7587	s=6.37936
LBGR=90	β=5	2897	726	2293	574	1925	482
	β=10	2293	575	1759	441	1439	360
	β=15	1925	483	1439	361	1151	288
LBGR=80	β=5	726	183	574	145	482	121
	β=10	575	145	441	111	360	91
	β=15	483	122	361	91	288	73
LBGR=70	β=5	324	82	256	65	215	54

	β=10	256	66	197	50	161	41
	β=15	216	55	161	41	129	33

s = Standard Deviation
LBGR = Lower Bound of Gray Region (% of Action Level)
β = Beta (%), Probability of mistakenly concluding that μ > action level
α = Alpha (%), Probability of mistakenly concluding that μ < action level
AL = Action Level (Threshold)

Cost of Sampling
The total cost of the completed sampling program depends on several cost inputs, some of which are fixed, and others that are based on the number of samples collected and measured. Based on the numbers of samples determined above, the estimated total cost of sampling and analysis at this site is $19,000.00, which averages out to a per sample cost of $527.78. The following table summarizes the inputs and resulting cost estimates.

COST INFORMATION			
Cost Details	**Per Analysis**	**Per Sample**	**36 Samples**
Field collection costs		$100.00	$3,600.00
Analytical costs	$400.00	$400.00	$14,400.00
Sum of Field & Analytical costs		**$500.00**	**$18,000.00**
Fixed planning and validation costs			$1,000.00
Total cost			**$19,000.00**

Data Analysis for Vanadium
The following data points were entered by the user for analysis.

Vanadium (mg/kg)										
Rank	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0	0.985	1.1	1.1	1.3	1.6	1.7	2.1	2.3	2.4	2.4
10	2.93	3.5	4.1	4.1	4.5	4.7	4.8	4.9	5.1	5.1
20	5.25	5.8	6.1	6.6	6.85	7	7.7	7.8	9.1	9.6
30	10.5	10.6	12.8	13.2	15.8	16	16.2	16.6	17.3	22.3
40	29.3									

SUMMARY STATISTICS for Vanadium	
n	41
Min	0.985
Max	29.3
Range	28.315
Mean	7.637
Median	5.25
Variance	40.719
StdDev	6.3812
Std Error	0.99657
Skewness	1.4668

Interquartile Range				7.885				
Percentiles								
1%	**5%**	**10%**	**25%**	**50%**	**75%**	**90%**	**95%**	**99%**
0.985	1.1	1.36	2.665	5.25	10.55	16.52	21.8	29.3

Outlier Test
Rosner's test for multiple outliers was performed to test whether the most extreme value is a statistical outlier. The test was conducted at the 5% significance level.

Data should not be excluded from analysis solely on the basis of the results of this or any other statistical test. If any values are flagged as possible outliers, further investigation is recommended to determine whether there is a plausible explanation that justifies removing or replacing them.

In using Rosner's test to detect up to 1 outlier, a test statistic R_1 is calculated, and compared with a critical value C_1 to test the hypothesis that there is one outlier in the data.

ROSNER'S OUTLIER TEST for Vanadium			
k	**Test Statistic R_k**	**5% Critical Value C_k**	**Significant?**
1	3.395	3.05	Yes

The test statistic 3.395 exceeded the corresponding critical value, therefore that test is significant and we conclude that the most extreme value is an outlier at the 5% significance level.

SUSPECTED OUTLIERS for Vanadium	
1	29.3

A normal distribution test indicated that the data do not appear to be normally distributed, so further investigation is recommended before using the results of this test. Because Rosner's test can be used only when the data without the suspected outlier are approximately normally distributed, a Shapiro-Wilk test for normality was performed at a 5% significance level.

NORMAL DISTRIBUTION TEST (excluding outliers)	
Shapiro-Wilk Test Statistic	0.8818
Shapiro-Wilk 5% Critical Value	0.94

The calculated Shapiro-Wilk test statistic is less than the 5% Shapiro-Wilk critical value, so the test rejects the hypothesis that the data are normal and concludes that the data, excluding the most extreme value, do not appear to follow a normal distribution at the 5% level of significance. Rosner's test may not be appropriate if the assumption of normally distributed data is not justified for this data set. Examine the Q-Q plot displayed below to further assess the normality of the data.

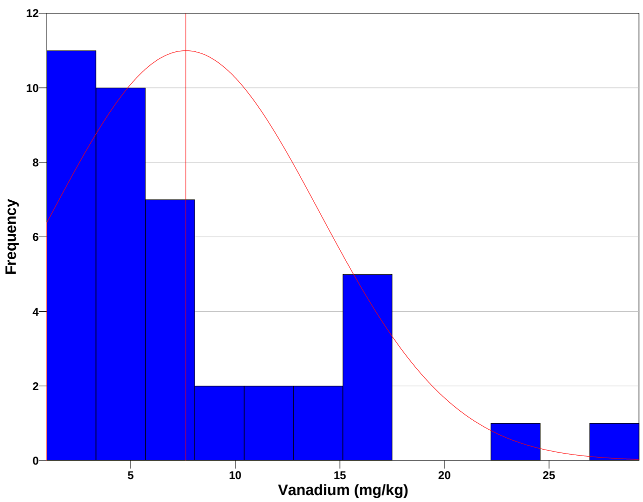
Data Plots for Vanadium
Graphical displays of the data are shown below.

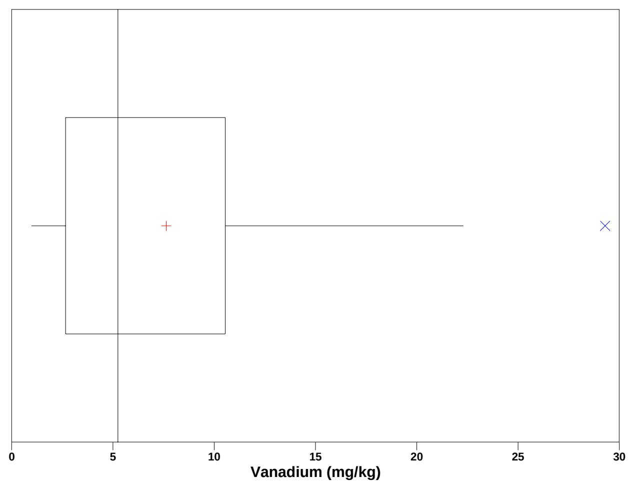
The Histogram is a plot of the fraction of the n observed data that fall within specified data “bins.” A histogram is generated by dividing the x axis (range of the observed data values) into "bins" and displaying the number of data in each bin as the height of a bar for the bin. The area of the bar is the fraction of the n data values that lie within the bin. The sum of the fractions for all bins equals one. A histogram is used to assess how the n data are distributed (spread) over their range of values. If the histogram is more or less symmetric and bell shaped, then the data may be normally distributed.

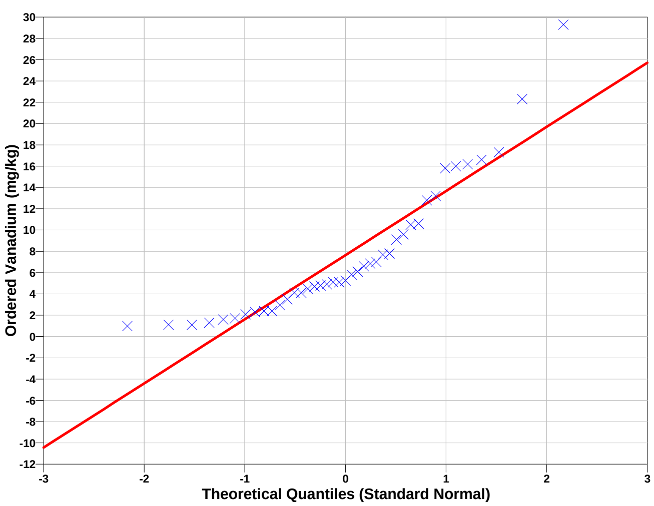
The Box and Whiskers plot is composed of a central box divided by a line, and with two lines extending out from the box, called the "whiskers". The line through the box is drawn at the median of the n data observed. The two ends of the box represent the 25^{th} and 75^{th} percentiles of the n data values, which are also called the lower and upper quartiles, respectively, of the data set. The sample mean (mean of the n data) is shown as a "+" sign. The upper whisker extends to

the largest data value that is less than the upper quartile plus 1.5 times the interquartile range (upper quartile minus the lower quartile). The lower whisker extends to the smallest data value that is greater than the lower quartile minus 1.5 times the interquartile range. Extreme data values (greater or smaller than the ends of the whiskers) are plotted individually as blue Xs. A Box and Whiskers plot is used to assess the symmetry of the distribution of the data set. If the distribution is symmetrical, the box is divided into two equal halves by the median, the whiskers will be the same length, and the number of extreme data points will be distributed equally on either end of the plot.

The Q-Q plot graphs the quantiles of a set of n data against the quantiles of a specific distribution. We show here only the Q-Q plot for an assumed normal distribution. The p^{th} quantile of a distribution of data is the data value, x_p, for which a fraction p of the distribution is less than x_p. If the data plotted on the normal distribution Q-Q plot closely follow a straight line, even at the ends of the line, then the data may be assumed to be normally distributed. If the data points deviate substantially from a linear line, then the data are not normally distributed.







□□□□□For more information on these plots consult Guidance for Data Quality Assessment, EPA QA/G-9, pgs 2.3-1 through 2.3-12. (http://www.epa.gov/quality/qa-docs.html).

Tests for Vanadium

A goodness-of-fit test was performed to test whether the data set had been drawn from an underlying normal distribution. The Shapiro-Wilk (SW) test was used to test the null hypothesis that the data are normally distributed. The test was conducted at the 5% significance level, i.e., the probability the test incorrectly rejects the null hypothesis was set at 0.05.

NORMAL DISTRIBUTION TEST	
Shapiro-Wilk Test Statistic	0.8548

Shapiro-Wilk 5% Critical Value	0.941

The calculated SW test statistic is less than the 5% Shapiro-Wilk critical value, so we can reject the hypothesis that the data are normal, or in other words the data do not appear to follow a normal distribution at the 5% level of significance. The Q-Q plot displayed above should be used to further assess the normality of the data.

Upper Confidence Limit on the True Mean

Two methods were used to compute the upper confidence limit (UCL) on the mean. The first is a parametric method that assumes a normal distribution. The second is the Chebyshev method, which requires no distributional assumption.

UCLs ON THE MEAN	
95% Parametric UCL	9.315
95% Non-Parametric (Chebyshev) UCL	11.981

Because the data do not appear to be normally distributed according to the goodness-of-fit test performed above, the non-parametric UCL (11.98) may be a more accurate upper confidence limit on the true mean.

One-Sample t-Test

A one-sample t-test was performed to compare the sample mean to the action level. The null hypothesis used is that the true mean equals or exceeds the action level (AL). The t-test was conducted at the 5% significance level. The sample value *t* was computed using the following equation:

$$t = \frac{\bar{x} - AL}{SE}$$

where

x is the sample mean of the n=41 data,

AL is the action level or threshold (7.8),

SE is the standard error = (standard deviation) / (square root of n).

This *t* was then compared with the critical value $t_{0.95}$, where $t_{0.95}$ is the value of the t distribution with n-1=40 degrees of freedom for which the proportion of the distribution to the left of $t_{0.95}$ is 0.95. The null hypothesis will be rejected if $t < -t_{0.95}$.

ONE-SAMPLE t-TEST		
t-statistic	**Critical Value $t_{0.95}$**	**Null Hypothesis**
-0.16361	1.6839	Cannot Reject

The test did not reject the null hypothesis that the mean value at the site exceeds the threshold, therefore conclude the true mean exceeds the threshold.

Because the data do not appear to be normally distributed, the MARSSIM Sign Test might be preferred over the One Sample t-Test. The following table represents the results of the MARSSIM Sign Test using the current data:

MARSSIM Sign Test		
Test Statistic (S+)	**95% Critical Value**	**Null Hypothesis**
27	25	Reject

Appendix B

VSP Reports of Calculated Minimum Sample Quantity

Report 3

Area of Concern – 1

Minimum Sample Quantity Calculation for Subsurface Soil using Human Health Benchmarks

Systematic sampling locations for comparing a mean with a fixed threshold (parametric)

Summary
This report summarizes the sampling design, associated statistical assumptions, as well as general guidelines for conducting post-sampling data analysis. Sampling plan components presented here include how many sampling locations to choose and where within the sampling area to collect those samples. The type of medium to sample (i.e., soil, groundwater, etc.) and how to analyze the samples (in-situ, fixed laboratory, etc.) are addressed in other sections of the sampling plan.

The following table summarizes the sampling design. A figure that shows sampling locations in the field and a table that lists sampling location coordinates are also provided below.

SUMMARY OF SAMPLING DESIGN	
Primary Objective of Design	Compare a site mean to a fixed threshold
Type of Sampling Design	Parametric
Sample Placement (Location) in the Field	Systematic with a random start location
Working (Null) Hypothesis	The mean value at the site exceeds the threshold
Formula for calculating number of sampling locations	Student's t-test
Calculated total number of samples	36
Number of samples on map [a]	36
Number of selected sample areas [b]	3
Specified sampling area [c]	2024225.46 ft^2
Size of grid / Area of grid cell [d]	254.808 feet / 56228.5 ft^2
Grid pattern	Triangular
Total cost of sampling [e]	$19,000.00

[a] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.
[b] The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.
[c] The sampling area is the total surface area of the selected colored sample areas on the map of the site.
[d] Size of grid / Area of grid cell gives the linear and square dimensions of the grid used to systematically place samples.
[e] Including measurement analyses and fixed overhead costs. See the Cost of Sampling section for an explanation of the costs presented here.

Area: AOC-1N					
X Coord	**Y Coord**	**Label**	**Value**	**Type**	**Historical**
1410655.1171	17204300.8648			Systematic	
1410909.9250	17204300.8648			Systematic	
1410527.7131	17204521.5349			Systematic	
1410782.5210	17204521.5349			Systematic	
1411037.3289	17204521.5349			Systematic	
1410655.1171	17204742.2050			Systematic	
1410909.9250	17204742.2050			Systematic	

Area: AOC-1S (1)					
X Coord	**Y Coord**	**Label**	**Value**	**Type**	**Historical**
1411023.7421	17202212.6230			Systematic	
1411278.5500	17202212.6230			Systematic	
1411151.1461	17202433.2931			Systematic	
1411405.9540	17202433.2931			Systematic	
1410768.9342	17202653.9632			Systematic	
1411023.7421	17202653.9632			Systematic	
1411278.5500	17202653.9632			Systematic	
1411533.3579	17202653.9632			Systematic	
1410896.3382	17202874.6333			Systematic	
1411151.1461	17202874.6333			Systematic	
1411405.9540	17202874.6333			Systematic	
1411660.7619	17202874.6333			Systematic	

1411023.7421	17203095.3034			Systematic	
1411278.5500	17203095.3034			Systematic	
1411533.3579	17203095.3034			Systematic	
1411788.1658	17203095.3034			Systematic	
1410641.5303	17203315.9735			Systematic	
1410896.3382	17203315.9735			Systematic	
1411151.1461	17203315.9735			Systematic	
1411405.9540	17203315.9735			Systematic	
1411660.7619	17203315.9735			Systematic	
1411915.5698	17203315.9735			Systematic	
1410768.9342	17203536.6436			Systematic	
1411023.7421	17203536.6436			Systematic	
1411278.5500	17203536.6436			Systematic	
1411533.3579	17203536.6436			Systematic	
1410896.3382	17203757.3138			Systematic	
1411151.1461	17203757.3138			Systematic	

Area: AOC-1S (2)					
X Coord	**Y Coord**	**Label**	**Value**	**Type**	**Historical**
1410705.4075	17202204.1921			Systematic	

Primary Sampling Objective
The primary purpose of sampling at this site is to compare a mean value of a site with a fixed threshold. The working hypothesis (or 'null' hypothesis) is that the mean value at the site is equal to or exceeds the threshold. The alternative hypothesis is that the mean value is less than the threshold. VSP calculates the number of samples required to reject the null hypothesis in favor of the alternative hypothesis, given a selected sampling approach and inputs to the associated equation.

Selected Sampling Approach
A parametric systematic sampling approach with a random start was used to determine the number of samples and to specify sampling locations. A parametric formula was chosen because the conceptual model and historical information (e.g., historical data from this site or a very similar site) indicate that parametric assumptions are reasonable. These assumptions will be examined in post-sampling data analysis.

Both parametric and non-parametric approaches rely on assumptions about the population. However, non-parametric approaches typically require fewer assumptions and allow for more uncertainty about the statistical distribution of values at the site. The trade-off is that if the parametric assumptions are valid, the required number of samples is usually less than the number of samples required by non-parametric approaches.

Locating the sample points over a systematic grid with a random start ensures spatial coverage of the site. Statistical analyses of systematically collected data are valid if a random start to the grid is used. One disadvantage of systematically collected samples is that spatial variability or patterns may not be discovered if the grid spacing is large relative to the spatial patterns.

Number of Total Samples: Calculation Equation and Inputs
The equation used to calculate the number of samples is based on a Student's t-test. For this site, the null hypothesis is rejected in favor of the alternative hypothesis if the sample mean is sufficiently smaller than the threshold. The number of samples to collect is calculated so that 1) there will be a high probability ($1-\beta$) of rejecting the null hypothesis if the alternative hypothesis is true and 2) a low probability (α) of rejecting the null hypothesis if the null hypothesis is true.

The formula used to calculate the number of samples is:

$$n = \frac{S^2}{\Delta^2}\left(Z_{1-\alpha} + Z_{1-\beta}\right)^2 + 0.5Z_{1-\alpha}^2$$

where

n is the number of samples,
S is the estimated standard deviation of the measured values including analytical error,
Δ is the width of the gray region,
α is the acceptable probability of incorrectly concluding the site mean is less than the threshold,
β is the acceptable probability of incorrectly concluding the site mean exceeds the threshold,
$Z_{1-\alpha}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\alpha}$ is 1-α,
$Z_{1-\beta}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\beta}$ is 1-β.

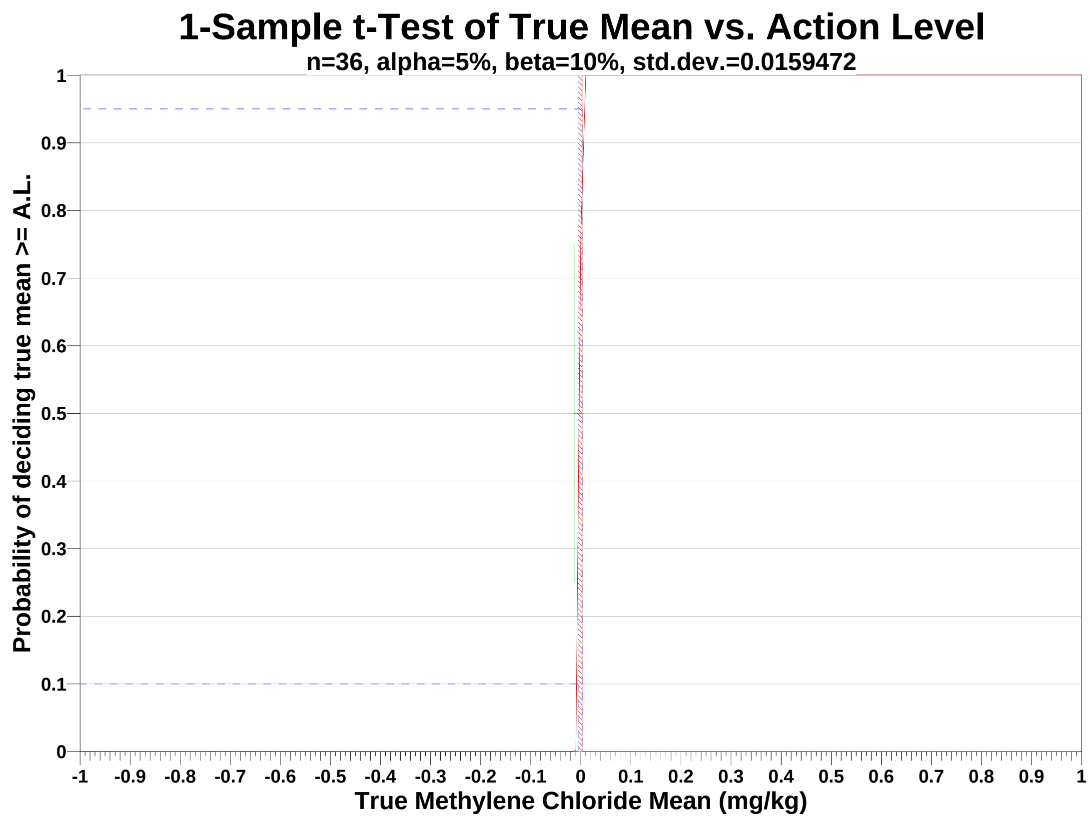
The values of these inputs that result in the calculated number of sampling locations are:

Analyte	**n**	**Parameter**					
		S	Δ	α	β	$Z_{1-\alpha}$ [a]	$Z_{1-\beta}$ [b]
Methylene Chloride	36	0.0159472 mg/kg	0.00797361 mg/kg	0.05	0.1	1.64485	1.28155

[a] This value is automatically calculated by VSP based upon the user defined value of α.
[b] This value is automatically calculated by VSP based upon the user defined value of β.

The following figure is a performance goal diagram, described in EPA's QA/G-4 guidance (EPA, 2000). It shows the probability of concluding the sample area is dirty on the vertical axis versus a range of possible true mean values for the site on the horizontal axis. This graph contains all of the inputs to the number of samples equation and pictorially represents the calculation.

The red vertical line is shown at the threshold (action limit) on the horizontal axis. The width of the gray shaded area is equal to Δ; the upper horizontal dashed blue line is positioned at 1-α on the vertical axis; the lower horizontal dashed blue line is positioned at β on the vertical axis. The vertical green line is positioned at one standard deviation below the threshold. The shape of the red curve corresponds to the estimates of variability. The calculated number of samples results in the curve that passes through the lower bound of Δ at β and the upper bound of Δ at 1-α. If any of the inputs change, the number of samples that result in the correct curve changes.



Statistical Assumptions

The assumptions associated with the formulas for computing the number of samples are:

1. the sample mean is normally distributed (this happens if the data are roughly symmetric or the sample size is more than 30; for extremely skewed data sets, additional samples may be required for the sample mean to be normally distributed),
2. the variance estimate, S^2, is reasonable and representative of the population being sampled,
3. the population values are not spatially or temporally correlated, and
4. the sampling locations will be selected probabilistically.

The first three assumptions will be assessed in a post data collection analysis. The last assumption is valid because the gridded sample locations were selected based on a random start.

Sensitivity Analysis

The sensitivity of the calculation of number of samples was explored by varying the standard deviation, lower bound of gray region (% of action level), beta (%), probability of mistakenly concluding that μ > action level and alpha (%), probability of mistakenly concluding that μ < action level. The following table shows the results of this analysis.

Number of Samples							
AL=0.0025		**α=5**		**α=10**		**α=15**	
		s=0.0318944	**s=0.0159472**	**s=0.0318944**	**s=0.0159472**	**s=0.0318944**	**s=0.0159472**
LBGR=90	**β=5**	176144	44037	139387	34848	117015	29254
	β=10	139388	34848	106927	26733	87453	21864
	β=15	117015	29255	87454	21864	69936	17485
LBGR=80	**β=5**	44037	11011	34848	8713	29254	7314
	β=10	34848	8713	26733	6684	21864	5467
	β=15	29255	7315	21864	5467	17485	4372
LBGR=70	**β=5**	19573	4895	15489	3873	13003	3251

	β=10	15489	3874	11882	2971	9718	2430
	β=15	13003	3252	9718	2431	7772	1944

s = Standard Deviation
LBGR = Lower Bound of Gray Region (% of Action Level)
β = Beta (%), Probability of mistakenly concluding that μ > action level
α = Alpha (%), Probability of mistakenly concluding that μ < action level
AL = Action Level (Threshold)

Cost of Sampling
The total cost of the completed sampling program depends on several cost inputs, some of which are fixed, and others that are based on the number of samples collected and measured. Based on the numbers of samples determined above, the estimated total cost of sampling and analysis at this site is $19,000.00, which averages out to a per sample cost of $527.78. The following table summarizes the inputs and resulting cost estimates.

COST INFORMATION			
Cost Details	**Per Analysis**	**Per Sample**	**36 Samples**
Field collection costs		$100.00	$3,600.00
Analytical costs	$400.00	$400.00	$14,400.00
Sum of Field & Analytical costs		**$500.00**	**$18,000.00**
Fixed planning and validation costs			$1,000.00
Total cost			**$19,000.00**

Data Analysis for Methylene Chloride
The following data points were entered by the user for analysis.

Methylene Chloride (mg/kg)										
Rank	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0	0.00135	0.00135	0.00135	0.00135	0.00135	0.0014	0.0014	0.0014	0.00145	0.00145
10	0.00145	0.00145	0.00145	0.00145	0.00145	0.0015	0.0015	0.003	0.0031	0.0031
20	0.0034	0.0034	0.0039	0.0042	0.0044	0.0044	0.0048	0.0049	0.0053	0.0058
30	0.006	0.0072	0.0076	0.0078	0.0078	0.0101	0.0143	0.0146	0.016	0.0334
40	0.0999									

SUMMARY STATISTICS for Methylene Chloride	
n	41
Min	0.00135
Max	0.0999
Range	0.09855
Mean	0.007378
Median	0.0034
Variance	0.00025431
StdDev	0.015947
Std Error	0.0024905
Skewness	5.2288

Interquartile Range				0.00515				
Percentiles								
1%	**5%**	**10%**	**25%**	**50%**	**75%**	**90%**	**95%**	**99%**
0.00135	0.00135	0.00135	0.00145	0.0034	0.0066	0.01454	0.03166	0.0999

Outlier Test
Rosner's test for multiple outliers was performed to test whether the most extreme value is a statistical outlier. The test was conducted at the 5% significance level.

Data should not be excluded from analysis solely on the basis of the results of this or any other statistical test. If any values are flagged as possible outliers, further investigation is recommended to determine whether there is a plausible explanation that justifies removing or replacing them.

In using Rosner's test to detect up to 1 outlier, a test statistic R_1 is calculated, and compared with a critical value C_1 to test the hypothesis that there is one outlier in the data.

ROSNER'S OUTLIER TEST for Methylene Chloride			
k	**Test Statistic R_k**	**5% Critical Value C_k**	**Significant?**
1	5.802	3.05	Yes

The test statistic 5.802 exceeded the corresponding critical value, therefore that test is significant and we conclude that the most extreme value is an outlier at the 5% significance level.

SUSPECTED OUTLIERS for Methylene Chloride	
1	0.0999

A normal distribution test indicated that the data do not appear to be normally distributed, so further investigation is recommended before using the results of this test. Because Rosner's test can be used only when the data without the suspected outlier are approximately normally distributed, a Shapiro-Wilk test for normality was performed at a 5% significance level.

NORMAL DISTRIBUTION TEST (excluding outliers)	
Shapiro-Wilk Test Statistic	0.6434
Shapiro-Wilk 5% Critical Value	0.94

The calculated Shapiro-Wilk test statistic is less than the 5% Shapiro-Wilk critical value, so the test rejects the hypothesis that the data are normal and concludes that the data, excluding the most extreme value, do not appear to follow a normal distribution at the 5% level of significance. Rosner's test may not be appropriate if the assumption of normally distributed data is not justified for this data set. Examine the Q-Q plot displayed below to further assess the normality of the data.

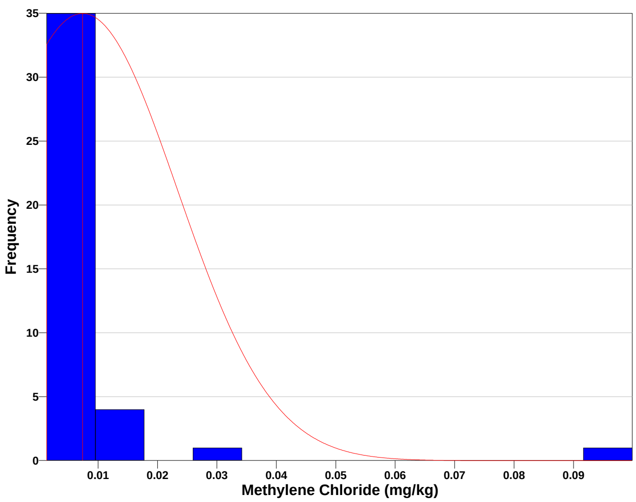
Data Plots for Methylene Chloride
Graphical displays of the data are shown below.

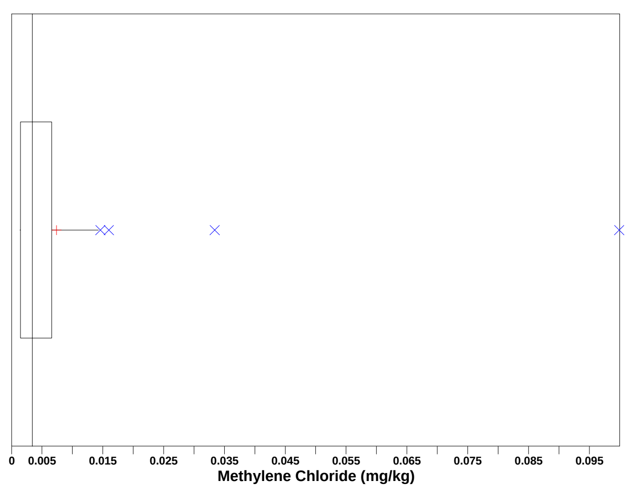
The Histogram is a plot of the fraction of the n observed data that fall within specified data “bins.” A histogram is generated by dividing the x axis (range of the observed data values) into "bins" and displaying the number of data in each bin as the height of a bar for the bin. The area of the bar is the fraction of the n data values that lie within the bin. The sum of the fractions for all bins equals one. A histogram is used to assess how the n data are distributed (spread) over their range of values. If the histogram is more or less symmetric and bell shaped, then the data may be normally distributed.

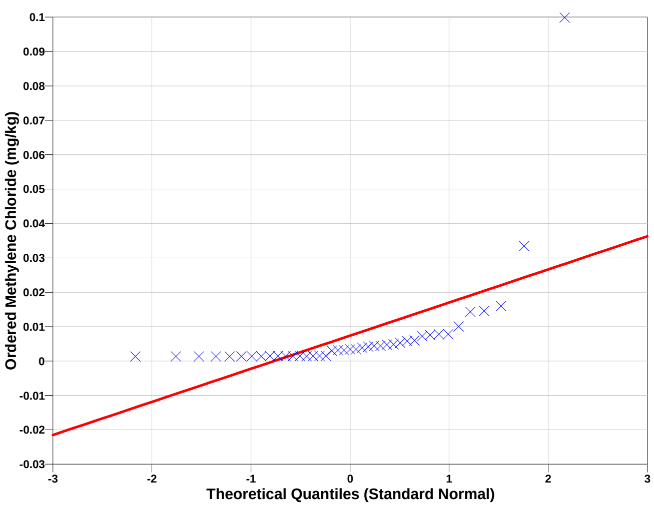
The Box and Whiskers plot is composed of a central box divided by a line, and with two lines extending out from the box, called the "whiskers". The line through the box is drawn at the median of the n data observed. The two ends of the box represent the 25^{th} and 75^{th} percentiles of the n data values, which are also called the lower and upper quartiles, respectively, of the data set. The sample mean (mean of the n data) is shown as a "+" sign. The upper whisker extends to

the largest data value that is less than the upper quartile plus 1.5 times the interquartile range (upper quartile minus the lower quartile). The lower whisker extends to the smallest data value that is greater than the lower quartile minus 1.5 times the interquartile range. Extreme data values (greater or smaller than the ends of the whiskers) are plotted individually as blue Xs. A Box and Whiskers plot is used to assess the symmetry of the distribution of the data set. If the distribution is symmetrical, the box is divided into two equal halves by the median, the whiskers will be the same length, and the number of extreme data points will be distributed equally on either end of the plot.

The Q-Q plot graphs the quantiles of a set of n data against the quantiles of a specific distribution. We show here only the Q-Q plot for an assumed normal distribution. The p^{th} quantile of a distribution of data is the data value, x_p, for which a fraction p of the distribution is less than x_p. If the data plotted on the normal distribution Q-Q plot closely follow a straight line, even at the ends of the line, then the data may be assumed to be normally distributed. If the data points deviate substantially from a linear line, then the data are not normally distributed.







□□□□□For more information on these plots consult Guidance for Data Quality Assessment, EPA QA/G-9, pgs 2.3-1 through 2.3-12. (http://www.epa.gov/quality/qa-docs.html).

Tests for Methylene Chloride

A goodness-of-fit test was performed to test whether the data set had been drawn from an underlying normal distribution. The Shapiro-Wilk (SW) test was used to test the null hypothesis that the data are normally distributed. The test was conducted at the 5% significance level, i.e., the probability the test incorrectly rejects the null hypothesis was set at 0.05.

NORMAL DISTRIBUTION TEST	
Shapiro-Wilk Test Statistic	0.3879

Shapiro-Wilk 5% Critical Value	0.941

The calculated SW test statistic is less than the 5% Shapiro-Wilk critical value, so we can reject the hypothesis that the data are normal, or in other words the data do not appear to follow a normal distribution at the 5% level of significance. The Q-Q plot displayed above should be used to further assess the normality of the data.

Upper Confidence Limit on the True Mean
Two methods were used to compute the upper confidence limit (UCL) on the mean. The first is a parametric method that assumes a normal distribution. The second is the Chebyshev method, which requires no distributional assumption.

UCLs ON THE MEAN	
95% Parametric UCL	0.011572
95% Non-Parametric (Chebyshev) UCL	0.018234

Because the data do not appear to be normally distributed according to the goodness-of-fit test performed above, the non-parametric UCL (0.01823) may be a more accurate upper confidence limit on the true mean.

One-Sample t-Test
A one-sample t-test was performed to compare the sample mean to the action level. The null hypothesis used is that the true mean equals or exceeds the action level (AL). The t-test was conducted at the 5% significance level. The sample value *t* was computed using the following equation:

$$t = \frac{\bar{x} - AL}{SE}$$

where
x is the sample mean of the n=41 data,
AL is the action level or threshold (0.0025),
SE is the standard error = (standard deviation) / (square root of n).

This *t* was then compared with the critical value $t_{0.95}$, where $t_{0.95}$ is the value of the t distribution with n-1=40 degrees of freedom for which the proportion of the distribution to the left of $t_{0.95}$ is 0.95. The null hypothesis will be rejected if $t < -t_{0.95}$.

ONE-SAMPLE t-TEST		
t-statistic	**Critical Value $t_{0.95}$**	**Null Hypothesis**
1.9586	1.6839	Cannot Reject

The test did not reject the null hypothesis that the mean value at the site exceeds the threshold, therefore conclude the true mean exceeds the threshold.

Because the data do not appear to be normally distributed, the MARSSIM Sign Test might be preferred over the One Sample t-Test. The following table represents the results of the MARSSIM Sign Test using the current data:

MARSSIM Sign Test		
Test Statistic (S+)	**95% Critical Value**	**Null Hypothesis**
17	26	Cannot Reject
Note: There may not be enough data to reject the null hypothesis (and conclude site is clean) with 95% confidence using the MARSSIM sign test.		

* - The report contents may have been modified or reformatted by end-user of software.

Appendix B

VSP Reports of Calculated Minimum Sample Quantity

Report 4

Area of Concern – 1

Minimum Sample Quantity Calculation for Subsurface Soil using Ecological Benchmarks

Systematic sampling locations for comparing a mean with a fixed threshold (parametric)

Summary
This report summarizes the sampling design, associated statistical assumptions, as well as general guidelines for conducting post-sampling data analysis. Sampling plan components presented here include how many sampling locations to choose and where within the sampling area to collect those samples. The type of medium to sample (i.e., soil, groundwater, etc.) and how to analyze the samples (in-situ, fixed laboratory, etc.) are addressed in other sections of the sampling plan.

The following table summarizes the sampling design. A figure that shows sampling locations in the field and a table that lists sampling location coordinates are also provided below.

SUMMARY OF SAMPLING DESIGN	
Primary Objective of Design	Compare a site mean to a fixed threshold
Type of Sampling Design	Parametric
Sample Placement (Location) in the Field	Systematic with a random start location
Working (Null) Hypothesis	The mean value at the site exceeds the threshold
Formula for calculating number of sampling locations	Student's t-test
Calculated total number of samples	15
Number of samples on map [a]	15
Number of selected sample areas [b]	3
Specified sampling area [c]	2024225.46 ft^2
Size of grid / Area of grid cell [d]	394.747 feet / 134948 ft^2
Grid pattern	Triangular
Total cost of sampling [e]	$8,500.00

[a] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.
[b] The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.
[c] The sampling area is the total surface area of the selected colored sample areas on the map of the site.
[d] Size of grid / Area of grid cell gives the linear and square dimensions of the grid used to systematically place samples.
[e] Including measurement analyses and fixed overhead costs. See the Cost of Sampling section for an explanation of the costs presented here.

Area: AOC-1N					
X Coord	Y Coord	Label	Value	Type	Historical
1410816.6521	17204427.4817			Systematic	
1411014.0255	17204769.3423			Systematic	

Area: AOC-1S (1)					
X Coord	Y Coord	Label	Value	Type	Historical
1410897.6693	17202071.4893			Systematic	
1411095.0427	17202413.3500			Systematic	
1411489.7894	17202413.3500			Systematic	
1410897.6693	17202755.2107			Systematic	
1411292.4160	17202755.2107			Systematic	
1411687.1627	17202755.2107			Systematic	
1411095.0427	17203097.0713			Systematic	
1411489.7894	17203097.0713			Systematic	
1411884.5361	17203097.0713			Systematic	
1410897.6693	17203438.9320			Systematic	
1411292.4160	17203438.9320			Systematic	
1411687.1627	17203438.9320			Systematic	
1411095.0427	17203780.7927			Systematic	

Area: AOC-1S (2)					
X Coord	Y Coord	Label	Value	Type	Historical

Primary Sampling Objective
The primary purpose of sampling at this site is to compare a mean value of a site with a fixed threshold. The working

hypothesis (or 'null' hypothesis) is that the mean value at the site is equal to or exceeds the threshold. The alternative hypothesis is that the mean value is less than the threshold. VSP calculates the number of samples required to reject the null hypothesis in favor of the alternative hypothesis, given a selected sampling approach and inputs to the associated equation.

Selected Sampling Approach
A parametric systematic sampling approach with a random start was used to determine the number of samples and to specify sampling locations. A parametric formula was chosen because the conceptual model and historical information (e.g., historical data from this site or a very similar site) indicate that parametric assumptions are reasonable. These assumptions will be examined in post-sampling data analysis.

Both parametric and non-parametric approaches rely on assumptions about the population. However, non-parametric approaches typically require fewer assumptions and allow for more uncertainty about the statistical distribution of values at the site. The trade-off is that if the parametric assumptions are valid, the required number of samples is usually less than the number of samples required by non-parametric approaches.

Locating the sample points over a systematic grid with a random start ensures spatial coverage of the site. Statistical analyses of systematically collected data are valid if a random start to the grid is used. One disadvantage of systematically collected samples is that spatial variability or patterns may not be discovered if the grid spacing is large relative to the spatial patterns.

Number of Total Samples: Calculation Equation and Inputs
The equation used to calculate the number of samples is based on a Student's t-test. For this site, the null hypothesis is rejected in favor of the alternative hypothesis if the sample mean is sufficiently smaller than the threshold. The number of samples to collect is calculated so that 1) there will be a high probability (1-β) of rejecting the null hypothesis if the alternative hypothesis is true and 2) a low probability (α) of rejecting the null hypothesis if the null hypothesis is true.

The formula used to calculate the number of samples is:

$$n = \frac{S^2}{\Delta^2}\left(Z_{1-\alpha} + Z_{1-\beta}\right)^2 + 0.5Z_{1-\alpha}^2$$

where
n is the number of samples,
S is the estimated standard deviation of the measured values including analytical error,
Δ is the width of the gray region,
α is the acceptable probability of incorrectly concluding the site mean is less than the threshold,
β is the acceptable probability of incorrectly concluding the site mean exceeds the threshold,
$Z_{1-\alpha}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\alpha}$ is 1-α,
$Z_{1-\beta}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\beta}$ is 1-β.

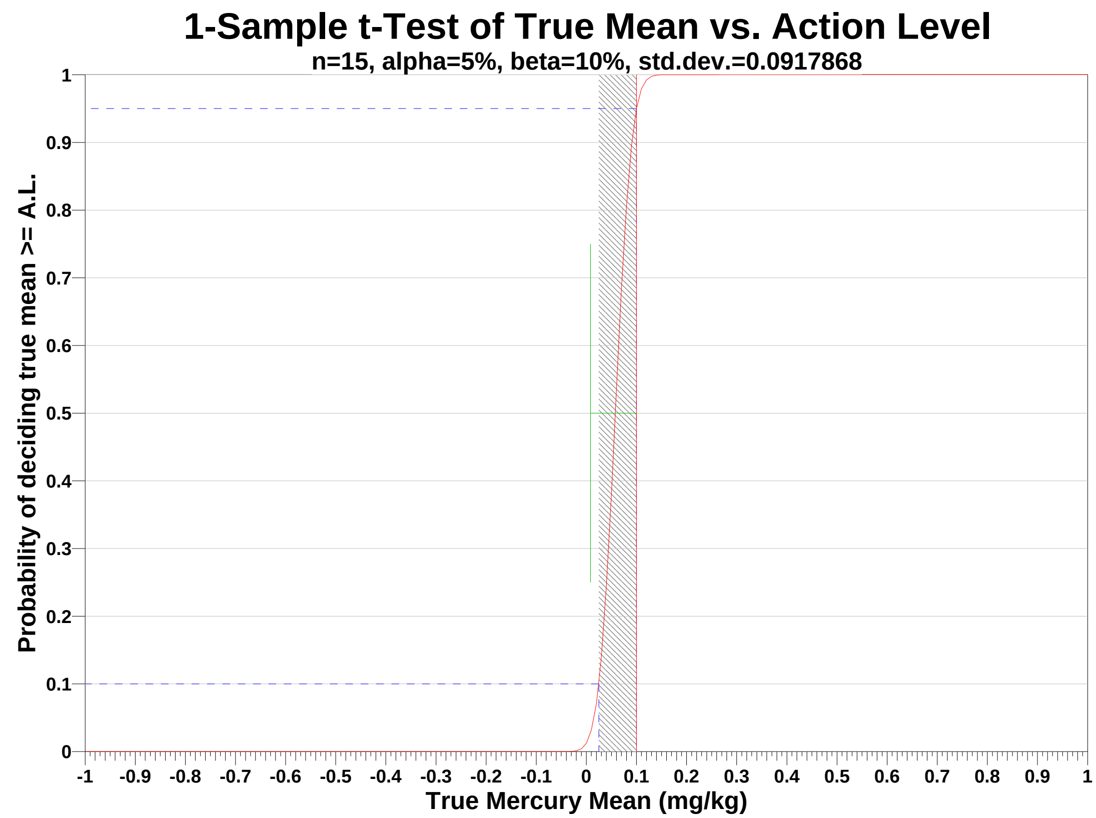
The values of these inputs that result in the calculated number of sampling locations are:

Analyte	n	Parameter					
		S	**Δ**	**α**	**β**	***$Z_{1-\alpha}$*** [a]	***$Z_{1-\beta}$*** [b]
Mercury	15	0.0917868 mg/kg	0.075222 mg/kg	0.05	0.1	1.64485	1.28155

[a] This value is automatically calculated by VSP based upon the user defined value of α.
[b] This value is automatically calculated by VSP based upon the user defined value of β.

The following figure is a performance goal diagram, described in EPA's QA/G-4 guidance (EPA, 2000). It shows the probability of concluding the sample area is dirty on the vertical axis versus a range of possible true mean values for the site on the horizontal axis. This graph contains all of the inputs to the number of samples equation and pictorially represents the calculation.

The red vertical line is shown at the threshold (action limit) on the horizontal axis. The width of the gray shaded area is equal to Δ; the upper horizontal dashed blue line is positioned at 1-α on the vertical axis; the lower horizontal dashed blue line is positioned at β on the vertical axis. The vertical green line is positioned at one standard deviation below the threshold. The shape of the red curve corresponds to the estimates of variability. The calculated number of samples results in the curve that passes through the lower bound of Δ at β and the upper bound of Δ at 1-α. If any of the inputs change, the number of samples that result in the correct curve changes.



Statistical Assumptions

The assumptions associated with the formulas for computing the number of samples are:

1. the sample mean is normally distributed (this happens if the data are roughly symmetric or the sample size is more than 30; for extremely skewed data sets, additional samples may be required for the sample mean to be normally distributed),
2. the variance estimate, S^2, is reasonable and representative of the population being sampled,
3. the population values are not spatially or temporally correlated, and
4. the sampling locations will be selected probabilistically.

The first three assumptions will be assessed in a post data collection analysis. The last assumption is valid because the gridded sample locations were selected based on a random start.

Sensitivity Analysis

The sensitivity of the calculation of number of samples was explored by varying the standard deviation, lower bound of gray region (% of action level), beta (%), probability of mistakenly concluding that μ > action level and alpha (%), probability of mistakenly concluding that μ < action level. The following table shows the results of this analysis.

Number of Samples							
AL=0.1		α=5		α=10		α=15	
		s=0.183574	s=0.0917868	s=0.183574	s=0.0917868	s=0.183574	s=0.0917868
LBGR=90	β=5	3649	914	2887	723	2424	607
	β=10	2888	723	2215	555	1812	454
	β=15	2425	608	1812	454	1449	363
LBGR=80	β=5	914	230	723	182	607	152
	β=10	723	182	555	140	454	114

	β=15	608	153	454	114	363	92
LBGR=70	**β=5**	407	103	322	81	270	68
	β=10	323	82	247	63	202	51
	β=15	271	69	203	52	162	41

s = Standard Deviation
LBGR = Lower Bound of Gray Region (% of Action Level)
β = Beta (%), Probability of mistakenly concluding that μ > action level
α = Alpha (%), Probability of mistakenly concluding that μ < action level
AL = Action Level (Threshold)

Cost of Sampling
The total cost of the completed sampling program depends on several cost inputs, some of which are fixed, and others that are based on the number of samples collected and measured. Based on the numbers of samples determined above, the estimated total cost of sampling and analysis at this site is $8,500.00, which averages out to a per sample cost of $566.67. The following table summarizes the inputs and resulting cost estimates.

COST INFORMATION			
Cost Details	**Per Analysis**	**Per Sample**	**15 Samples**
Field collection costs		$100.00	$1,500.00
Analytical costs	$400.00	$400.00	$6,000.00
Sum of Field & Analytical costs		**$500.00**	**$7,500.00**
Fixed planning and validation costs			$1,000.00
Total cost			**$8,500.00**

Data Analysis for Mercury
The following data points were entered by the user for analysis.

Mercury (mg/kg)										
Rank	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0	0.00035	0.00036	0.000365	0.00038	0.00038	0.00038	0.000385	0.00043	0.00044	0.0013
10	0.0017	0.0021	0.0024	0.0025	0.0026	0.0038	0.0043	0.0045	0.0046	0.0048
20	0.0048	0.0051	0.0053	0.0065	0.0072	0.0073	0.0077	0.008	0.01	0.011
30	0.012	0.012	0.013	0.014	0.019	0.033	0.048	0.054	0.055	0.055
40	0.59									

SUMMARY STATISTICS for Mercury	
n	41
Min	0.00035
Max	0.59
Range	0.58965
Mean	0.02478
Median	0.0048
Variance	0.0084248
StdDev	0.091787

Std Error				0.014335				
Skewness				6.13				
Interquartile Range				0.0105				
Percentiles								
1%	**5%**	**10%**	**25%**	**50%**	**75%**	**90%**	**95%**	**99%**
0.00035	0.0003605	0.00038	0.0015	0.0048	0.012	0.0528	0.055	0.59

Outlier Test
Rosner's test for multiple outliers was performed to test whether the most extreme value is a statistical outlier. The test was conducted at the 5% significance level.

Data should not be excluded from analysis solely on the basis of the results of this or any other statistical test. If any values are flagged as possible outliers, further investigation is recommended to determine whether there is a plausible explanation that justifies removing or replacing them.

In using Rosner's test to detect up to 1 outlier, a test statistic R_1 is calculated, and compared with a critical value C_1 to test the hypothesis that there is one outlier in the data.

ROSNER'S OUTLIER TEST for Mercury			
k	**Test Statistic R_k**	**5% Critical Value C_k**	**Significant?**
1	6.158	3.05	Yes

The test statistic 6.158 exceeded the corresponding critical value, therefore that test is significant and we conclude that the most extreme value is an outlier at the 5% significance level.

SUSPECTED OUTLIERS for Mercury	
1	0.59

A normal distribution test indicated that the data do not appear to be normally distributed, so further investigation is recommended before using the results of this test. Because Rosner's test can be used only when the data without the suspected outlier are approximately normally distributed, a Shapiro-Wilk test for normality was performed at a 5% significance level.

NORMAL DISTRIBUTION TEST (excluding outliers)	
Shapiro-Wilk Test Statistic	0.6364
Shapiro-Wilk 5% Critical Value	0.94

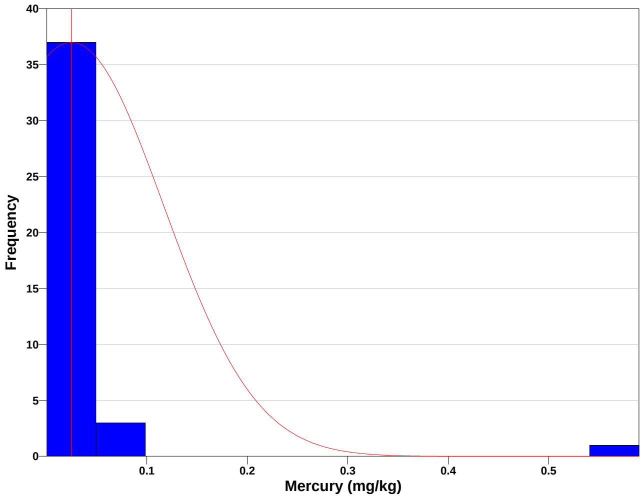
The calculated Shapiro-Wilk test statistic is less than the 5% Shapiro-Wilk critical value, so the test rejects the hypothesis that the data are normal and concludes that the data, excluding the most extreme value, do not appear to follow a normal distribution at the 5% level of significance. Rosner's test may not be appropriate if the assumption of normally distributed data is not justified for this data set. Examine the Q-Q plot displayed below to further assess the normality of the data.

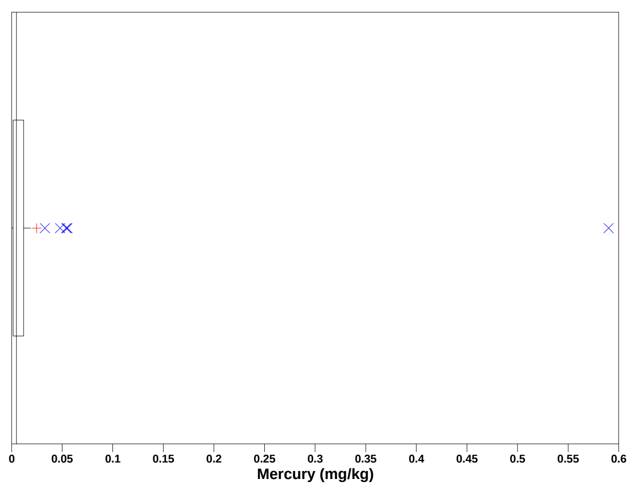
Data Plots for Mercury
Graphical displays of the data are shown below.

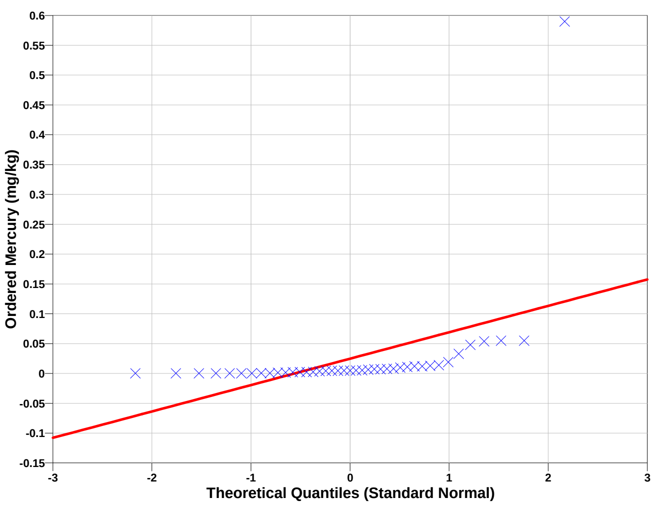
The Histogram is a plot of the fraction of the n observed data that fall within specified data “bins.” A histogram is generated by dividing the x axis (range of the observed data values) into "bins" and displaying the number of data in each bin as the height of a bar for the bin. The area of the bar is the fraction of the n data values that lie within the bin. The sum of the fractions for all bins equals one. A histogram is used to assess how the n data are distributed (spread) over their range of values. If the histogram is more or less symmetric and bell shaped, then the data may be normally distributed.

The Box and Whiskers plot is composed of a central box divided by a line, and with two lines extending out from the box, called the "whiskers". The line through the box is drawn at the median of the n data observed. The two ends of the box represent the 25^{th} and 75^{th} percentiles of the n data values, which are also called the lower and upper quartiles, respectively, of the data set. The sample mean (mean of the n data) is shown as a "+" sign. The upper whisker extends to the largest data value that is less than the upper quartile plus 1.5 times the interquartile range (upper quartile minus the lower quartile). The lower whisker extends to the smallest data value that is greater than the lower quartile minus 1.5 times the interquartile range. Extreme data values (greater or smaller than the ends of the whiskers) are plotted individually as blue Xs. A Box and Whiskers plot is used to assess the symmetry of the distribution of the data set. If the distribution is symmetrical, the box is divided into two equal halves by the median, the whiskers will be the same length, and the number of extreme data points will be distributed equally on either end of the plot.

The Q-Q plot graphs the quantiles of a set of n data against the quantiles of a specific distribution. We show here only the Q-Q plot for an assumed normal distribution. The p^{th} quantile of a distribution of data is the data value, x_p, for which a fraction p of the distribution is less than x_p. If the data plotted on the normal distribution Q-Q plot closely follow a straight line, even at the ends of the line, then the data may be assumed to be normally distributed. If the data points deviate substantially from a linear line, then the data are not normally distributed.







□□□□□For more information on these plots consult Guidance for Data Quality Assessment, EPA QA/G-9, pgs 2.3-1 through 2.3-12. (http://www.epa.gov/quality/qa-docs.html).

Tests for Mercury

A goodness-of-fit test was performed to test whether the data set had been drawn from an underlying normal distribution. The Shapiro-Wilk (SW) test was used to test the null hypothesis that the data are normally distributed. The test was conducted at the 5% significance level, i.e., the probability the test incorrectly rejects the null hypothesis was set at 0.05.

NORMAL DISTRIBUTION TEST

Shapiro-Wilk Test Statistic	0.2612
Shapiro-Wilk 5% Critical Value	0.941

The calculated SW test statistic is less than the 5% Shapiro-Wilk critical value, so we can reject the hypothesis that the data are normal, or in other words the data do not appear to follow a normal distribution at the 5% level of significance. The Q-Q plot displayed above should be used to further assess the normality of the data.

Upper Confidence Limit on the True Mean
Two methods were used to compute the upper confidence limit (UCL) on the mean. The first is a parametric method that assumes a normal distribution. The second is the Chebyshev method, which requires no distributional assumption.

UCLs ON THE MEAN	
95% Parametric UCL	0.048917
95% Non-Parametric (Chebyshev) UCL	0.087263

Because the data do not appear to be normally distributed according to the goodness-of-fit test performed above, the non-parametric UCL (0.08726) may be a more accurate upper confidence limit on the true mean.

One-Sample t-Test
A one-sample t-test was performed to compare the sample mean to the action level. The null hypothesis used is that the true mean equals or exceeds the action level (AL). The t-test was conducted at the 5% significance level. The sample value *t* was computed using the following equation:

$$t = \frac{\bar{x} - AL}{SE}$$

where
x is the sample mean of the n=41 data,
AL is the action level or threshold (0.1),
SE is the standard error = (standard deviation) / (square root of n).

This *t* was then compared with the critical value $t_{0.95}$, where $t_{0.95}$ is the value of the t distribution with n-1=40 degrees of freedom for which the proportion of the distribution to the left of $t_{0.95}$ is 0.95. The null hypothesis will be rejected if $t < -t_{0.95}$.

ONE-SAMPLE t-TEST		
t-statistic	**Critical Value $t_{0.95}$**	**Null Hypothesis**
-5.2474	1.6839	Reject

The test rejected the null hypothesis that the mean value at the site exceeds the threshold, therefore conclude the true mean is less than the threshold.

Because the data do not appear to be normally distributed, the MARSSIM Sign Test might be preferred over the One Sample t-Test. The following table represents the results of the MARSSIM Sign Test using the current data:

MARSSIM Sign Test		
Test Statistic (S+)	**95% Critical Value**	**Null Hypothesis**
40	26	Reject

This report was automatically produced* by Visual Sample Plan (VSP) software version 6.3.
Software and documentation available at http://vsp.pnnl.gov

* - The report contents may have been modified or reformatted by end-user of software.

Appendix B

VSP Reports of Calculated Minimum Sample Quantity

Report 5

Area of Concern – 1

Minimum Sample Quantity Calculation for Ground Water using Human Health Benchmarks

Systematic sampling locations for comparing a mean with a fixed threshold (parametric)

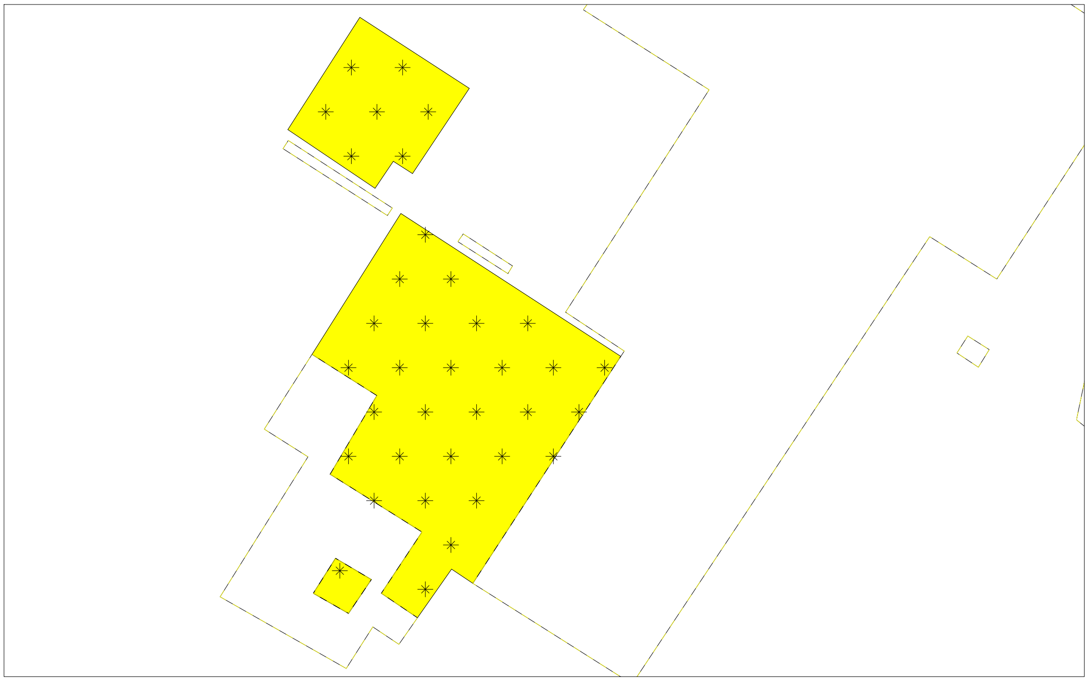
Summary

This report summarizes the sampling design, associated statistical assumptions, as well as general guidelines for conducting post-sampling data analysis. Sampling plan components presented here include how many sampling locations to choose and where within the sampling area to collect those samples. The type of medium to sample (i.e., soil, groundwater, etc.) and how to analyze the samples (in-situ, fixed laboratory, etc.) are addressed in other sections of the sampling plan.

The following table summarizes the sampling design. A figure that shows sampling locations in the field and a table that lists sampling location coordinates are also provided below.

SUMMARY OF SAMPLING DESIGN	
Primary Objective of Design	Compare a site mean to a fixed threshold
Type of Sampling Design	Parametric
Sample Placement (Location) in the Field	Systematic with a random start location
Working (Null) Hypothesis	The mean value at the site exceeds the threshold
Formula for calculating number of sampling locations	Student's t-test
Calculated total number of samples	36
Number of samples on map [a]	36
Number of selected sample areas [b]	3
Specified sampling area [c]	2024225.46 ft^2
Size of grid / Area of grid cell [d]	254.808 feet / 56228.5 ft^2
Grid pattern	Triangular
Total cost of sampling [e]	$19,000.00

[a] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.
[b] The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.
[c] The sampling area is the total surface area of the selected colored sample areas on the map of the site.
[d] Size of grid / Area of grid cell gives the linear and square dimensions of the grid used to systematically place samples.
[e] Including measurement analyses and fixed overhead costs. See the Cost of Sampling section for an explanation of the costs presented here.



Area: AOC-1N					
X Coord	**Y Coord**	**Label**	**Value**	**Type**	**Historical**
1410718.7143	17204260.3664			Systematic	
1410973.5222	17204260.3664			Systematic	
1410591.3104	17204481.0365			Systematic	
1410846.1183	17204481.0365			Systematic	
1411100.9261	17204481.0365			Systematic	
1410718.7143	17204701.7066			Systematic	
1410973.5222	17204701.7066			Systematic	

Area: AOC-1S (1)					
X Coord	**Y Coord**	**Label**	**Value**	**Type**	**Historical**
1411087.1589	17202103.9129			Systematic	
1411214.5629	17202324.5830			Systematic	
1410832.3510	17202545.2531			Systematic	
1411087.1589	17202545.2531			Systematic	
1411341.9668	17202545.2531			Systematic	
1410704.9471	17202765.9233			Systematic	
1410959.7550	17202765.9233			Systematic	
1411214.5629	17202765.9233			Systematic	
1411469.3708	17202765.9233			Systematic	
1411724.1787	17202765.9233			Systematic	
1410832.3510	17202986.5934			Systematic	
1411087.1589	17202986.5934			Systematic	

1411341.9668	17202986.5934			Systematic	
1411596.7747	17202986.5934			Systematic	
1411851.5826	17202986.5934			Systematic	
1410704.9471	17203207.2635			Systematic	
1410959.7550	17203207.2635			Systematic	
1411214.5629	17203207.2635			Systematic	
1411469.3708	17203207.2635			Systematic	
1411724.1787	17203207.2635			Systematic	
1411978.9865	17203207.2635			Systematic	
1410832.3510	17203427.9336			Systematic	
1411087.1589	17203427.9336			Systematic	
1411341.9668	17203427.9336			Systematic	
1411596.7747	17203427.9336			Systematic	
1410959.7550	17203648.6037			Systematic	
1411214.5629	17203648.6037			Systematic	
1411087.1589	17203869.2738			Systematic	

Area: AOC-1S (2)					
X Coord	**Y Coord**	**Label**	**Value**	**Type**	**Historical**
1410661.3649	17202196.4589			Systematic	

Primary Sampling Objective
The primary purpose of sampling at this site is to compare a mean value of a site with a fixed threshold. The working hypothesis (or 'null' hypothesis) is that the mean value at the site is equal to or exceeds the threshold. The alternative hypothesis is that the mean value is less than the threshold. VSP calculates the number of samples required to reject the null hypothesis in favor of the alternative hypothesis, given a selected sampling approach and inputs to the associated equation.

Selected Sampling Approach
A parametric systematic sampling approach with a random start was used to determine the number of samples and to specify sampling locations. A parametric formula was chosen because the conceptual model and historical information (e.g., historical data from this site or a very similar site) indicate that parametric assumptions are reasonable. These assumptions will be examined in post-sampling data analysis.

Both parametric and non-parametric approaches rely on assumptions about the population. However, non-parametric approaches typically require fewer assumptions and allow for more uncertainty about the statistical distribution of values at the site. The trade-off is that if the parametric assumptions are valid, the required number of samples is usually less than the number of samples required by non-parametric approaches.

Locating the sample points over a systematic grid with a random start ensures spatial coverage of the site. Statistical analyses of systematically collected data are valid if a random start to the grid is used. One disadvantage of systematically collected samples is that spatial variability or patterns may not be discovered if the grid spacing is large relative to the spatial patterns.

Number of Total Samples: Calculation Equation and Inputs
The equation used to calculate the number of samples is based on a Student's t-test. For this site, the null hypothesis is rejected in favor of the alternative hypothesis if the sample mean is sufficiently smaller than the threshold. The number of samples to collect is calculated so that 1) there will be a high probability ($1-\beta$) of rejecting the null hypothesis if the alternative hypothesis is true and 2) a low probability (α) of rejecting the null hypothesis if the null hypothesis is true.

The formula used to calculate the number of samples is:

$$n = \frac{S^2}{\Delta^2}\left(Z_{1-\alpha} + Z_{1-\beta}\right)^2 + 0.5Z_{1-\alpha}^2$$

where

n	is the number of samples,
S	is the estimated standard deviation of the measured values including analytical error,
Δ	is the width of the gray region,
α	is the acceptable probability of incorrectly concluding the site mean is less than the threshold,
β	is the acceptable probability of incorrectly concluding the site mean exceeds the threshold,
$Z_{1-\alpha}$	is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\alpha}$ is $1-\alpha$,
$Z_{1-\beta}$	is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\beta}$ is $1-\beta$.

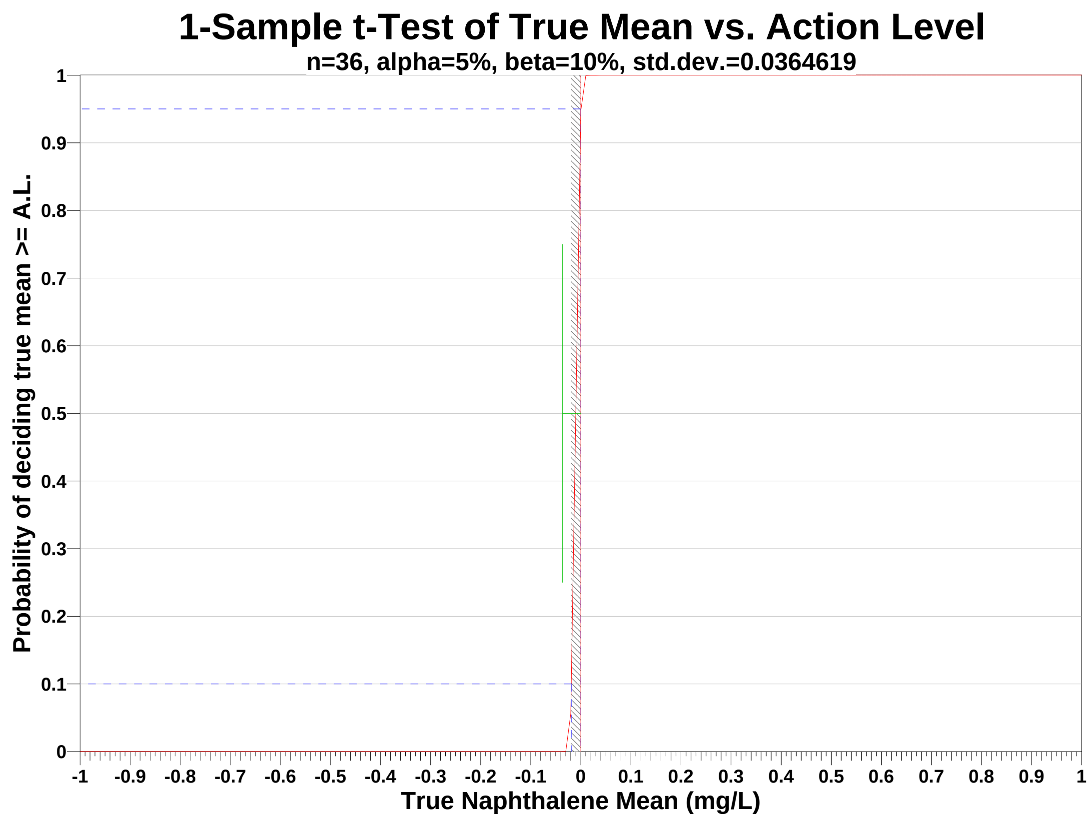
The values of these inputs that result in the calculated number of sampling locations are:

Analyte	**n**	**Parameter**					
		S	Δ	α	β	$Z_{1-\alpha}$ [a]	$Z_{1-\beta}$ [b]
Naphthalene	36	0.0364619 mg/L	0.0182309 mg/L	0.05	0.1	1.64485	1.28155

[a] This value is automatically calculated by VSP based upon the user defined value of α.
[b] This value is automatically calculated by VSP based upon the user defined value of β.

The following figure is a performance goal diagram, described in EPA's QA/G-4 guidance (EPA, 2000). It shows the probability of concluding the sample area is dirty on the vertical axis versus a range of possible true mean values for the site on the horizontal axis. This graph contains all of the inputs to the number of samples equation and pictorially represents the calculation.

The red vertical line is shown at the threshold (action limit) on the horizontal axis. The width of the gray shaded area is equal to Δ; the upper horizontal dashed blue line is positioned at $1-\alpha$ on the vertical axis; the lower horizontal dashed blue line is positioned at β on the vertical axis. The vertical green line is positioned at one standard deviation below the threshold. The shape of the red curve corresponds to the estimates of variability. The calculated number of samples results in the curve that passes through the lower bound of Δ at β and the upper bound of Δ at $1-\alpha$. If any of the inputs change, the number of samples that result in the correct curve changes.



Statistical Assumptions
The assumptions associated with the formulas for computing the number of samples are:

1. the sample mean is normally distributed (this happens if the data are roughly symmetric or the sample size is more than 30; for extremely skewed data sets, additional samples may be required for the sample mean to be normally distributed),
2. the variance estimate, S^2, is reasonable and representative of the population being sampled,
3. the population values are not spatially or temporally correlated, and
4. the sampling locations will be selected probabilistically.

The first three assumptions will be assessed in a post data collection analysis. The last assumption is valid because the gridded sample locations were selected based on a random start.

Sensitivity Analysis
The sensitivity of the calculation of number of samples was explored by varying the standard deviation, lower bound of gray region (% of action level), beta (%), probability of mistakenly concluding that μ > action level and alpha (%), probability of mistakenly concluding that μ < action level. The following table shows the results of this analysis.

Number of Samples							
AL=0.00014		**α=5**		**α=10**		**α=15**	
		s=0.0729238	**s=0.0364619**	**s=0.0729238**	**s=0.0364619**	**s=0.0729238**	**s=0.0364619**
LBGR=90	**β=5**	293627697	73406926	232354684	58088672	195060406	48765102
	β=10	232354684	58088672	178243900	44560976	145781945	36445487
	β=15	195060407	48765103	145781945	36445487	116580335	29145084
LBGR=80	**β=5**	73406926	18351733	58088672	14522169	48765102	12191276
	β=10	58088672	14522170	44560976	11140245	36445487	9111373
	β=15	48765103	12191277	36445487	9111373	29145084	7286272
LBGR=70	**β=5**	32625301	8156327	25817188	6454298	21673379	5418346

	β=10	25817189	6454299	19804879	4951221	16197995	4049499
	β=15	21673380	5418346	16197995	4049500	12953371	3238344

s = Standard Deviation
LBGR = Lower Bound of Gray Region (% of Action Level)
β = Beta (%), Probability of mistakenly concluding that μ > action level
α = Alpha (%), Probability of mistakenly concluding that μ < action level
AL = Action Level (Threshold)

Cost of Sampling
The total cost of the completed sampling program depends on several cost inputs, some of which are fixed, and others that are based on the number of samples collected and measured. Based on the numbers of samples determined above, the estimated total cost of sampling and analysis at this site is $19,000.00, which averages out to a per sample cost of $527.78. The following table summarizes the inputs and resulting cost estimates.

COST INFORMATION			
Cost Details	**Per Analysis**	**Per Sample**	**36 Samples**
Field collection costs		$100.00	$3,600.00
Analytical costs	$400.00	$400.00	$14,400.00
Sum of Field & Analytical costs		**$500.00**	**$18,000.00**
Fixed planning and validation costs			$1,000.00
Total cost			**$19,000.00**

Data Analysis for Naphthalene
The following data points were entered by the user for analysis.

Naphthalene (mg/L)										
Rank	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0	0.00075	0.00075	0.00075	0.00075	0.00075	0.00075	0.00075	0.00075	0.00075	0.00075
10	0.00075	0.00075	0.00075	0.00075	0.00075	0.0021	0.0053	0.0256	0.0273	0.163

SUMMARY STATISTICS for Naphthalene	
n	20
Min	0.00075
Max	0.163
Range	0.16225
Mean	0.011728
Median	0.00075
Variance	0.0013295
StdDev	0.036462
Std Error	0.0081531
Skewness	4.1585
Interquartile Range	0.0010125

Percentiles								
1%	**5%**	**10%**	**25%**	**50%**	**75%**	**90%**	**95%**	**99%**

0.00075	0.00075	0.00075	0.00075	0.00075	0.001763	0.02713	0.1562	0.163

Outlier Test
Dixon's extreme value test was performed to test whether the lowest value is a statistical outlier. The test was conducted at the 5% significance level.

Data should not be excluded from analysis solely on the basis of the results of this or any other statistical test. If any values are flagged as possible outliers, further investigation is recommended to determine whether there is a plausible explanation that justifies removing or replacing them.

DIXON'S OUTLIER TEST for Naphthalene	
Dixon Test Statistic	0
Dixon 5% Critical Value	0.45

The calculated test statistic does not exceed the critical value, so the test cannot reject the null hypothesis that there are no outliers in the data, and concludes that the minimum value 0.00075 is not an outlier at the 5% significance level.

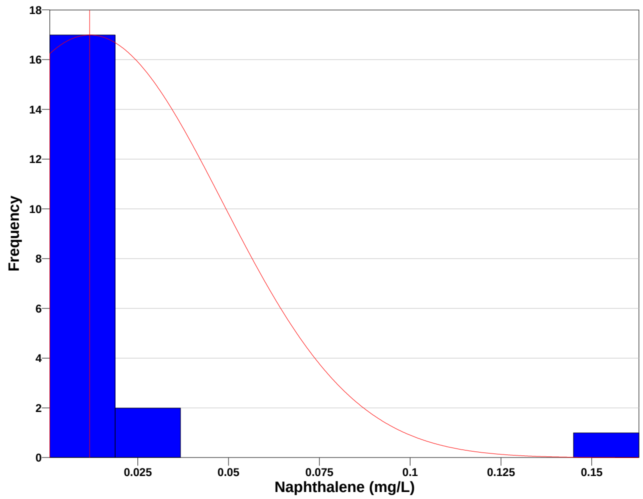
A normal distribution test indicated that the data do not appear to be normally distributed, so further investigation is recommended before using the results of this test.

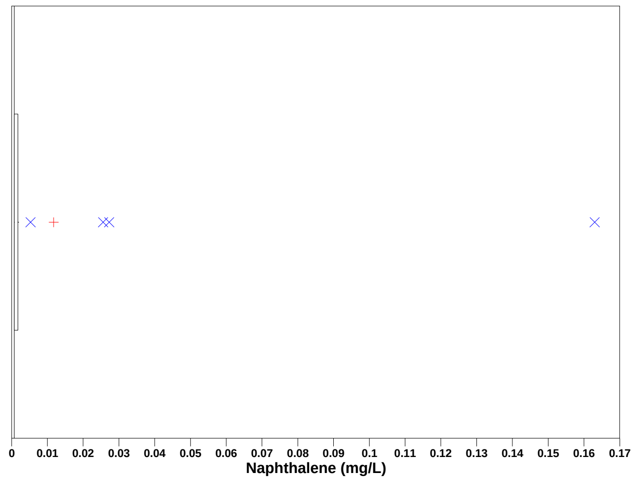
Data Plots for Naphthalene
Graphical displays of the data are shown below.

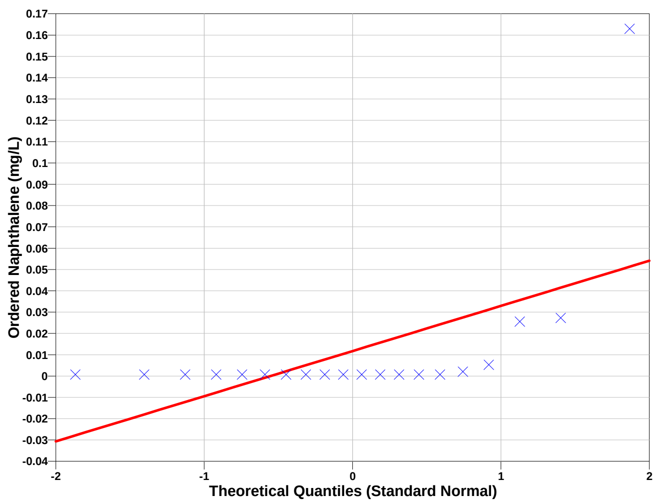
The Histogram is a plot of the fraction of the n observed data that fall within specified data “bins.” A histogram is generated by dividing the x axis (range of the observed data values) into "bins" and displaying the number of data in each bin as the height of a bar for the bin. The area of the bar is the fraction of the n data values that lie within the bin. The sum of the fractions for all bins equals one. A histogram is used to assess how the n data are distributed (spread) over their range of values. If the histogram is more or less symmetric and bell shaped, then the data may be normally distributed.

The Box and Whiskers plot is composed of a central box divided by a line, and with two lines extending out from the box, called the "whiskers". The line through the box is drawn at the median of the n data observed. The two ends of the box represent the 25^{th} and 75^{th} percentiles of the n data values, which are also called the lower and upper quartiles, respectively, of the data set. The sample mean (mean of the n data) is shown as a "+" sign. The upper whisker extends to the largest data value that is less than the upper quartile plus 1.5 times the interquartile range (upper quartile minus the lower quartile). The lower whisker extends to the smallest data value that is greater than the lower quartile minus 1.5 times the interquartile range. Extreme data values (greater or smaller than the ends of the whiskers) are plotted individually as blue Xs. A Box and Whiskers plot is used to assess the symmetry of the distribution of the data set. If the distribution is symmetrical, the box is divided into two equal halves by the median, the whiskers will be the same length, and the number of extreme data points will be distributed equally on either end of the plot.

The Q-Q plot graphs the quantiles of a set of n data against the quantiles of a specific distribution. We show here only the Q-Q plot for an assumed normal distribution. The p^{th} quantile of a distribution of data is the data value, x_p, for which a fraction p of the distribution is less than x_p. If the data plotted on the normal distribution Q-Q plot closely follow a straight line, even at the ends of the line, then the data may be assumed to be normally distributed. If the data points deviate substantially from a linear line, then the data are not normally distributed.







For more information on these plots consult Guidance for Data Quality Assessment, EPA QA/G-9, pgs 2.3-1 through 2.3-12. (http://www.epa.gov/quality/qa-docs.html).

Tests for Naphthalene

A goodness-of-fit test was performed to test whether the data set had been drawn from an underlying normal distribution. The Shapiro-Wilk (SW) test was used to test the null hypothesis that the data are normally distributed. The test was conducted at the 5% significance level, i.e., the probability the test incorrectly rejects the null hypothesis was set at 0.05.

NORMAL DISTRIBUTION TEST	
Shapiro-Wilk Test Statistic	0.3416
Shapiro-Wilk 5% Critical Value	0.905

The calculated SW test statistic is less than the 5% Shapiro-Wilk critical value, so we can reject the hypothesis that the data are normal, or in other words the data do not appear to follow a normal distribution at the 5% level of significance. The Q-Q plot displayed above should be used to further assess the normality of the data.

Upper Confidence Limit on the True Mean

Two methods were used to compute the upper confidence limit (UCL) on the mean. The first is a parametric method that assumes a normal distribution. The second is the Chebyshev method, which requires no distributional assumption.

UCLs ON THE MEAN	
95% Parametric UCL	0.025825

95% Non-Parametric (Chebyshev) UCL	0.047266

Because the data do not appear to be normally distributed according to the goodness-of-fit test performed above, the non-parametric UCL (0.04727) may be a more accurate upper confidence limit on the true mean.

One-Sample t-Test

A one-sample t-test was performed to compare the sample mean to the action level. The null hypothesis used is that the true mean equals or exceeds the action level (AL). The t-test was conducted at the 5% significance level. The sample value *t* was computed using the following equation:

$$t = \frac{\bar{x} - AL}{SE}$$

where
x is the sample mean of the n=20 data,
AL is the action level or threshold (0.00014),
SE is the standard error = (standard deviation) / (square root of n).

This *t* was then compared with the critical value $t_{0.95}$, where $t_{0.95}$ is the value of the t distribution with n-1=19 degrees of freedom for which the proportion of the distribution to the left of $t_{0.95}$ is 0.95. The null hypothesis will be rejected if $t < -t_{0.95}$.

ONE-SAMPLE t-TEST		
t-statistic	**Critical Value $t_{0.95}$**	**Null Hypothesis**
1.4212	1.7291	Cannot Reject

The test did not reject the null hypothesis that the mean value at the site exceeds the threshold, therefore conclude the true mean exceeds the threshold.

Because the data do not appear to be normally distributed, the MARSSIM Sign Test might be preferred over the One Sample t-Test. The following table represents the results of the MARSSIM Sign Test using the current data:

MARSSIM Sign Test		
Test Statistic (S+)	**95% Critical Value**	**Null Hypothesis**
0	14	Cannot Reject
Note: There may not be enough data to reject the null hypothesis (and conclude site is clean) with 95% confidence using the MARSSIM sign test.		

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Software and documentation available at http://vsp.pnnl.gov

* - The report contents may have been modified or reformatted by end-user of software.

Appendix B

VSP Reports of Calculated Minimum Sample Quantity

Report 6

Area of Concern – 3

Minimum Sample Quantity Calculation for Surface Soil using Human Health Benchmarks

Systematic sampling locations for comparing a mean with a fixed threshold (parametric)

Summary
This report summarizes the sampling design, associated statistical assumptions, as well as general guidelines for conducting post-sampling data analysis. Sampling plan components presented here include how many sampling locations to choose and where within the sampling area to collect those samples. The type of medium to sample (i.e., soil, groundwater, etc.) and how to analyze the samples (in-situ, fixed laboratory, etc.) are addressed in other sections of the sampling plan.

The following table summarizes the sampling design. A figure that shows sampling locations in the field and a table that lists sampling location coordinates are also provided below.

SUMMARY OF SAMPLING DESIGN	
Primary Objective of Design	Compare a site mean to a fixed threshold
Type of Sampling Design	Parametric
Sample Placement (Location) in the Field	Systematic with a random start location
Working (Null) Hypothesis	The mean value at the site exceeds the threshold
Formula for calculating number of sampling locations	Student's t-test
Calculated total number of samples	7
Number of samples on map [a]	7
Number of selected sample areas [b]	1
Specified sampling area [c]	4421854.81 ft^2
Size of grid / Area of grid cell [d]	854.059 feet / 631694 ft^2
Grid pattern	Triangular
Total cost of sampling [e]	$4,500.00

[a] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.
[b] The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.
[c] The sampling area is the total surface area of the selected colored sample areas on the map of the site.
[d] Size of grid / Area of grid cell gives the linear and square dimensions of the grid used to systematically place samples.
[e] Including measurement analyses and fixed overhead costs. See the Cost of Sampling section for an explanation of the costs presented here.

Area: AOC-3 OW					
X Coord	**Y Coord**	**Label**	**Value**	**Type**	**Historical**
1411810.0334	17201931.1537			Systematic	
1412664.0924	17203410.4274			Systematic	
1412237.0629	17204150.0642			Systematic	
1412664.0924	17204889.7011			Systematic	
1413518.1515	17204889.7011			Systematic	
1414372.2106	17204889.7011			Systematic	
1413091.1220	17205629.3379			Systematic	

Primary Sampling Objective
The primary purpose of sampling at this site is to compare a mean value of a site with a fixed threshold. The working hypothesis (or 'null' hypothesis) is that the mean value at the site is equal to or exceeds the threshold. The alternative hypothesis is that the mean value is less than the threshold. VSP calculates the number of samples required to reject the null hypothesis in favor of the alternative hypothesis, given a selected sampling approach and inputs to the associated equation.

Selected Sampling Approach
A parametric systematic sampling approach with a random start was used to determine the number of samples and to specify sampling locations. A parametric formula was chosen because the conceptual model and historical information (e.g., historical data from this site or a very similar site) indicate that parametric assumptions are reasonable. These assumptions will be examined in post-sampling data analysis.

Both parametric and non-parametric approaches rely on assumptions about the population. However, non-parametric approaches typically require fewer assumptions and allow for more uncertainty about the statistical distribution of values at the site. The trade-off is that if the parametric assumptions are valid, the required number of samples is usually less than the number of samples required by non-parametric approaches.

Locating the sample points over a systematic grid with a random start ensures spatial coverage of the site. Statistical analyses of systematically collected data are valid if a random start to the grid is used. One disadvantage of systematically collected samples is that spatial variability or patterns may not be discovered if the grid spacing is large relative to the spatial patterns.

Number of Total Samples: Calculation Equation and Inputs

The equation used to calculate the number of samples is based on a Student's t-test. For this site, the null hypothesis is rejected in favor of the alternative hypothesis if the sample mean is sufficiently smaller than the threshold. The number of samples to collect is calculated so that 1) there will be a high probability ($1-\beta$) of rejecting the null hypothesis if the alternative hypothesis is true and 2) a low probability (α) of rejecting the null hypothesis if the null hypothesis is true.

The formula used to calculate the number of samples is:

$$n = \frac{S^2}{\Delta^2}\left(Z_{1-\alpha} + Z_{1-\beta}\right)^2 + 0.5Z_{1-\alpha}^2$$

where

n	is the number of samples,
S	is the estimated standard deviation of the measured values including analytical error,
Δ	is the width of the gray region,
α	is the acceptable probability of incorrectly concluding the site mean is less than the threshold,
β	is the acceptable probability of incorrectly concluding the site mean exceeds the threshold,
$Z_{1-\alpha}$	is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\alpha}$ is $1-\alpha$,
$Z_{1-\beta}$	is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\beta}$ is $1-\beta$.

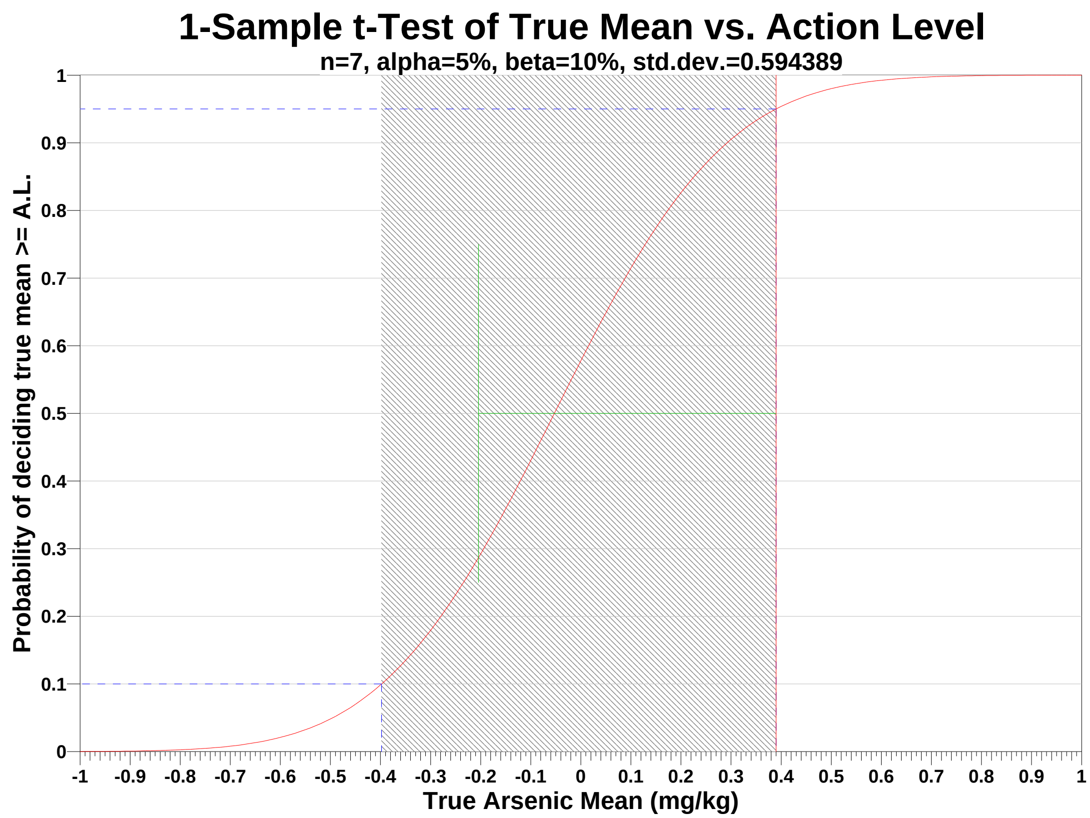
The values of these inputs that result in the calculated number of sampling locations are:

Analyte	n	Parameter					
		S	Δ	α	β	$Z_{1-\alpha}$ [a]	$Z_{1-\beta}$ [b]
Arsenic	7	0.594389 mg/kg	0.787857 mg/kg	0.05	0.1	1.64485	1.28155

[a] This value is automatically calculated by VSP based upon the user defined value of α.
[b] This value is automatically calculated by VSP based upon the user defined value of β.

The following figure is a performance goal diagram, described in EPA's QA/G-4 guidance (EPA, 2000). It shows the probability of concluding the sample area is dirty on the vertical axis versus a range of possible true mean values for the site on the horizontal axis. This graph contains all of the inputs to the number of samples equation and pictorially represents the calculation.

The red vertical line is shown at the threshold (action limit) on the horizontal axis. The width of the gray shaded area is equal to Δ; the upper horizontal dashed blue line is positioned at $1-\alpha$ on the vertical axis; the lower horizontal dashed blue line is positioned at β on the vertical axis. The vertical green line is positioned at one standard deviation below the threshold. The shape of the red curve corresponds to the estimates of variability. The calculated number of samples results in the curve that passes through the lower bound of Δ at β and the upper bound of Δ at $1-\alpha$. If any of the inputs change, the number of samples that result in the correct curve changes.



Statistical Assumptions

The assumptions associated with the formulas for computing the number of samples are:

1. the sample mean is normally distributed (this happens if the data are roughly symmetric or the sample size is more than 30; for extremely skewed data sets, additional samples may be required for the sample mean to be normally distributed),
2. the variance estimate, S^2, is reasonable and representative of the population being sampled,
3. the population values are not spatially or temporally correlated, and
4. the sampling locations will be selected probabilistically.

The first three assumptions will be assessed in a post data collection analysis. The last assumption is valid because the gridded sample locations were selected based on a random start.

Sensitivity Analysis

The sensitivity of the calculation of number of samples was explored by varying the standard deviation, lower bound of gray region (% of action level), beta (%), probability of mistakenly concluding that μ > action level and alpha (%), probability of mistakenly concluding that μ < action level. The following table shows the results of this analysis.

Number of Samples							
AL=0.39		α=5		α=10		α=15	
		s=1.18878	**s=0.594389**	**s=1.18878**	**s=0.594389**	**s=1.18878**	**s=0.594389**
LBGR=90	**β=5**	10057	2516	7958	1991	6681	1671
	β=10	7959	1991	6105	1527	4993	1249
	β=15	6682	1672	4994	1249	3993	999
LBGR=80	**β=5**	2516	630	1991	499	1671	419
	β=10	1991	499	1527	383	1249	313
	β=15	1672	419	1249	313	999	251
LBGR=70	**β=5**	1119	281	885	222	743	187

	β=10	886	223	680	171	556	140
	β=15	744	187	556	140	445	112

s = Standard Deviation
LBGR = Lower Bound of Gray Region (% of Action Level)
β = Beta (%), Probability of mistakenly concluding that μ > action level
α = Alpha (%), Probability of mistakenly concluding that μ < action level
AL = Action Level (Threshold)

Cost of Sampling
The total cost of the completed sampling program depends on several cost inputs, some of which are fixed, and others that are based on the number of samples collected and measured. Based on the numbers of samples determined above, the estimated total cost of sampling and analysis at this site is $4,500.00, which averages out to a per sample cost of $642.86. The following table summarizes the inputs and resulting cost estimates.

COST INFORMATION			
Cost Details	**Per Analysis**	**Per Sample**	**7 Samples**
Field collection costs		$100.00	$700.00
Analytical costs	$400.00	$400.00	$2,800.00
Sum of Field & Analytical costs		**$500.00**	**$3,500.00**
Fixed planning and validation costs			$1,000.00
Total cost			**$4,500.00**

Data Analysis for Arsenic
The following data points were entered by the user for analysis.

Arsenic (mg/kg)										
Rank	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0	0.72	0.96	0.965	1	1	1.1	2.5			

SUMMARY STATISTICS for Arsenic								
n	7							
Min	0.72							
Max	2.5							
Range	1.78							
Mean	1.1779							
Median	1							
Variance	0.3533							
StdDev	0.59439							
Std Error	0.22466							
Skewness	2.4261							
Interquartile Range	0.14							
Percentiles								
1%	**5%**	**10%**	**25%**	**50%**	**75%**	**90%**	**95%**	**99%**
0.72	0.72	0.72	0.96	1	1.1	2.5	2.5	2.5

Outlier Test
Dixon's extreme value test was performed to test whether the lowest value is a statistical outlier. The test was conducted at the 5% significance level.

Data should not be excluded from analysis solely on the basis of the results of this or any other statistical test. If any values are flagged as possible outliers, further investigation is recommended to determine whether there is a plausible explanation that justifies removing or replacing them.

DIXON'S OUTLIER TEST for Arsenic	
Dixon Test Statistic	0.13483
Dixon 5% Critical Value	0.507

The calculated test statistic does not exceed the critical value, so the test cannot reject the null hypothesis that there are no outliers in the data, and concludes that the minimum value 0.72 is not an outlier at the 5% significance level.

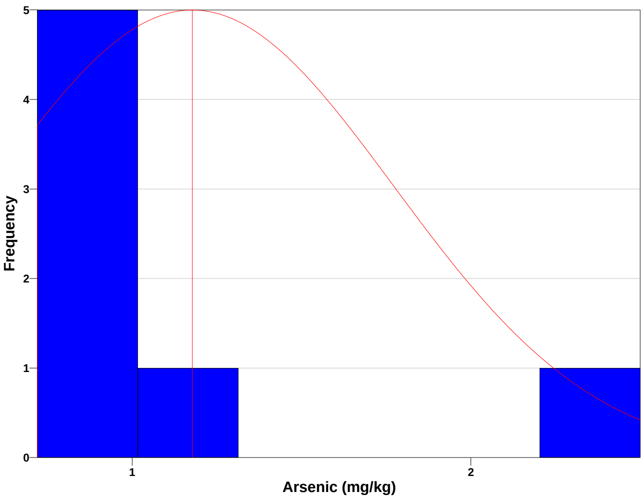
A normal distribution test indicated that the data do not appear to be normally distributed, so further investigation is recommended before using the results of this test.

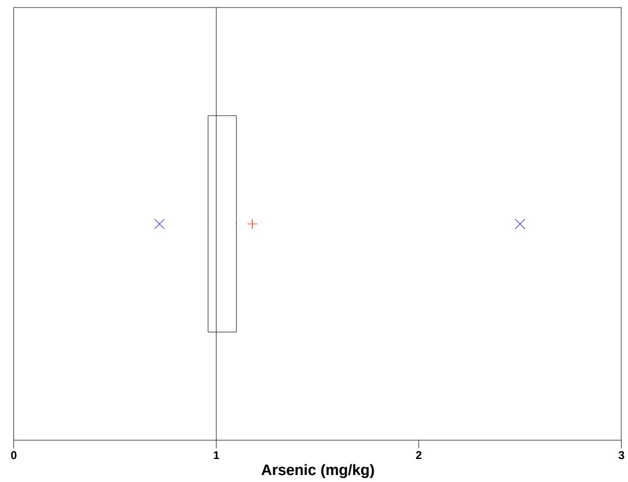
Data Plots for Arsenic
Graphical displays of the data are shown below.

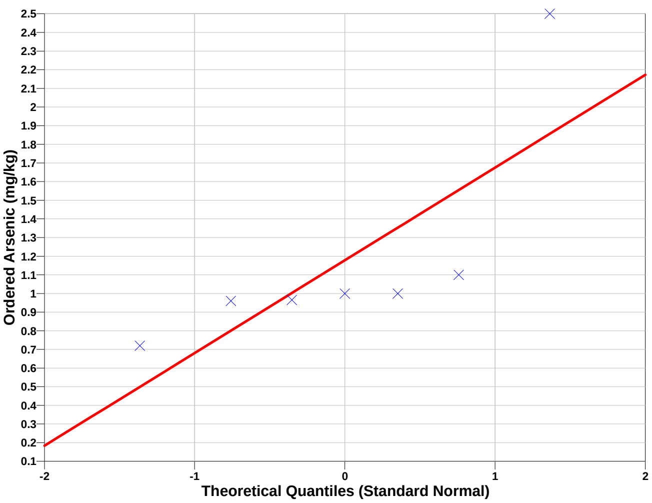
The Histogram is a plot of the fraction of the n observed data that fall within specified data “bins.” A histogram is generated by dividing the x axis (range of the observed data values) into "bins" and displaying the number of data in each bin as the height of a bar for the bin. The area of the bar is the fraction of the n data values that lie within the bin. The sum of the fractions for all bins equals one. A histogram is used to assess how the n data are distributed (spread) over their range of values. If the histogram is more or less symmetric and bell shaped, then the data may be normally distributed.

The Box and Whiskers plot is composed of a central box divided by a line, and with two lines extending out from the box, called the "whiskers". The line through the box is drawn at the median of the n data observed. The two ends of the box represent the 25^{th} and 75^{th} percentiles of the n data values, which are also called the lower and upper quartiles, respectively, of the data set. The sample mean (mean of the n data) is shown as a "+" sign. The upper whisker extends to the largest data value that is less than the upper quartile plus 1.5 times the interquartile range (upper quartile minus the lower quartile). The lower whisker extends to the smallest data value that is greater than the lower quartile minus 1.5 times the interquartile range. Extreme data values (greater or smaller than the ends of the whiskers) are plotted individually as blue Xs. A Box and Whiskers plot is used to assess the symmetry of the distribution of the data set. If the distribution is symmetrical, the box is divided into two equal halves by the median, the whiskers will be the same length, and the number of extreme data points will be distributed equally on either end of the plot.

The Q-Q plot graphs the quantiles of a set of n data against the quantiles of a specific distribution. We show here only the Q-Q plot for an assumed normal distribution. The p^{th} quantile of a distribution of data is the data value, x_p, for which a fraction p of the distribution is less than x_p. If the data plotted on the normal distribution Q-Q plot closely follow a straight line, even at the ends of the line, then the data may be assumed to be normally distributed. If the data points deviate substantially from a linear line, then the data are not normally distributed.







□□□□□For more information on these plots consult Guidance for Data Quality Assessment, EPA QA/G-9, pgs 2.3-1 through 2.3-12. (http://www.epa.gov/quality/qa-docs.html).

Tests for Arsenic

A goodness-of-fit test was performed to test whether the data set had been drawn from an underlying normal distribution. The Shapiro-Wilk (SW) test was used to test the null hypothesis that the data are normally distributed. The test was conducted at the 5% significance level, i.e., the probability the test incorrectly rejects the null hypothesis was set at 0.05.

NORMAL DISTRIBUTION TEST	
Shapiro-Wilk Test Statistic	0.6313
Shapiro-Wilk 5% Critical Value	0.803

The calculated SW test statistic is less than the 5% Shapiro-Wilk critical value, so we can reject the hypothesis that the data are normal, or in other words the data do not appear to follow a normal distribution at the 5% level of significance. The Q-Q plot displayed above should be used to further assess the normality of the data.

Upper Confidence Limit on the True Mean

Two methods were used to compute the upper confidence limit (UCL) on the mean. The first is a parametric method that assumes a normal distribution. The second is the Chebyshev method, which requires no distributional assumption.

UCLs ON THE MEAN	
95% Parametric UCL	1.6144

95% Non-Parametric (Chebyshev) UCL	2.1571

Because the data do not appear to be normally distributed according to the goodness-of-fit test performed above, the non-parametric UCL (2.157) may be a more accurate upper confidence limit on the true mean.

One-Sample t-Test

A one-sample t-test was performed to compare the sample mean to the action level. The null hypothesis used is that the true mean equals or exceeds the action level (AL). The t-test was conducted at the 5% significance level. The sample value *t* was computed using the following equation:

$$t = \frac{\bar{x} - AL}{SE}$$

where

x is the sample mean of the n=7 data,

AL is the action level or threshold (0.39),

SE is the standard error = (standard deviation) / (square root of n).

This t was then compared with the critical value $t_{0.95}$, where $t_{0.95}$ is the value of the t distribution with n-1=6 degrees of freedom for which the proportion of the distribution to the left of $t_{0.95}$ is 0.95. The null hypothesis will be rejected if $t < -t_{0.95}$.

ONE-SAMPLE t-TEST		
t-statistic	**Critical Value $t_{0.95}$**	**Null Hypothesis**
3.5069	1.9432	Cannot Reject

The test did not reject the null hypothesis that the mean value at the site exceeds the threshold, therefore conclude the true mean exceeds the threshold.

Because the data do not appear to be normally distributed, the MARSSIM Sign Test might be preferred over the One Sample t-Test. The following table represents the results of the MARSSIM Sign Test using the current data:

MARSSIM Sign Test		
Test Statistic (S+)	**95% Critical Value**	**Null Hypothesis**
0	6	Cannot Reject
Note: There may not be enough data to reject the null hypothesis (and conclude site is clean) with 95% confidence using the MARSSIM sign test.		

Appendix B

VSP Reports of Calculated Minimum Sample Quantity

Report 7

Area of Concern – 3

Minimum Sample Quantity Calculation for Surface Soil using Ecological Benchmarks

Systematic sampling locations for comparing a mean with a fixed threshold (parametric)

Summary
This report summarizes the sampling design, associated statistical assumptions, as well as general guidelines for conducting post-sampling data analysis. Sampling plan components presented here include how many sampling locations to choose and where within the sampling area to collect those samples. The type of medium to sample (i.e., soil, groundwater, etc.) and how to analyze the samples (in-situ, fixed laboratory, etc.) are addressed in other sections of the sampling plan.

The following table summarizes the sampling design for Analyte 1, the driving analyte (the analyte which required the largest number of samples). A figure that shows sampling locations in the field and a table that lists sampling location coordinates are also provided below.

SUMMARY OF SAMPLING DESIGN	
Primary Objective of Design	Compare a site mean to a fixed threshold
Type of Sampling Design	Parametric
Sample Placement (Location) in the Field	Systematic with a random start location
Working (Null) Hypothesis	The mean value at the site exceeds the threshold
Formula for calculating number of sampling locations	Student's t-test
Calculated total number of samples	32
Number of samples on map [a]	32
Number of selected sample areas [b]	1
Specified sampling area [c]	4421854.81 ft^2
Size of grid / Area of grid cell [d]	399.45 feet / 138183 ft^2
Grid pattern	Triangular
Total cost of sampling [e]	$17,000.00

[a] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.
[b] The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.
[c] The sampling area is the total surface area of the selected colored sample areas on the map of the site.
[d] Size of grid / Area of grid cell gives the linear and square dimensions of the grid used to systematically place samples.
[e] Including measurement analyses and fixed overhead costs. See the Cost of Sampling section for an explanation of the costs presented here.

Area: AOC-3 OW					
X Coord	Y Coord	Label	Value	Type	Historical
1412057.1911	17201884.3811			Systematic	
1411458.0168	17202230.3145			Systematic	
1412256.9159	17202230.3145			Systematic	
1411657.7416	17202576.2480			Systematic	
1411857.4663	17202922.1814			Systematic	
1412656.3654	17202922.1814			Systematic	
1412456.6406	17203268.1149			Systematic	
1412856.0902	17203268.1149			Systematic	
1412656.3654	17203614.0484			Systematic	
1413055.8150	17203614.0484			Systematic	
1413255.5397	17203959.9818			Systematic	
1413654.9893	17203959.9818			Systematic	
1414054.4388	17203959.9818			Systematic	
1412656.3654	17204305.9153			Systematic	
1413455.2645	17204305.9153			Systematic	
1413854.7141	17204305.9153			Systematic	
1414254.1636	17204305.9153			Systematic	
1412456.6406	17204651.8487			Systematic	
1412856.0902	17204651.8487			Systematic	
1413255.5397	17204651.8487			Systematic	
1413654.9893	17204651.8487			Systematic	
1414453.8884	17204651.8487			Systematic	

1412256.9159	17204997.7822			Systematic	
1412656.3654	17204997.7822			Systematic	
1413055.8150	17204997.7822			Systematic	
1413455.2645	17204997.7822			Systematic	
1414254.1636	17204997.7822			Systematic	
1412456.6406	17205343.7156			Systematic	
1413255.5397	17205343.7156			Systematic	
1413654.9893	17205343.7156			Systematic	
1412656.3654	17205689.6491			Systematic	
1413055.8150	17205689.6491			Systematic	

Primary Sampling Objective

The primary purpose of sampling at this site is to compare a mean value of a site with a fixed threshold. The working hypothesis (or 'null' hypothesis) is that the mean value at the site is equal to or exceeds the threshold. The alternative hypothesis is that the mean value is less than the threshold. VSP calculates the number of samples required to reject the null hypothesis in favor of the alternative hypothesis, given a selected sampling approach and inputs to the associated equation.

Selected Sampling Approach

A parametric systematic sampling approach with a random start was used to determine the number of samples and to specify sampling locations. A parametric formula was chosen because the conceptual model and historical information (e.g., historical data from this site or a very similar site) indicate that parametric assumptions are reasonable. These assumptions will be examined in post-sampling data analysis.

Both parametric and non-parametric approaches rely on assumptions about the population. However, non-parametric approaches typically require fewer assumptions and allow for more uncertainty about the statistical distribution of values at the site. The trade-off is that if the parametric assumptions are valid, the required number of samples is usually less than the number of samples required by non-parametric approaches.

Locating the sample points over a systematic grid with a random start ensures spatial coverage of the site. Statistical analyses of systematically collected data are valid if a random start to the grid is used. One disadvantage of systematically collected samples is that spatial variability or patterns may not be discovered if the grid spacing is large relative to the spatial patterns.

Number of Total Samples: Calculation Equation and Inputs

The equation used to calculate the number of samples is based on a Student's t-test. For this site, the null hypothesis is rejected in favor of the alternative hypothesis if the sample mean is sufficiently smaller than the threshold. The number of samples to collect is calculated so that 1) there will be a high probability ($1-\beta$) of rejecting the null hypothesis if the alternative hypothesis is true and 2) a low probability (α) of rejecting the null hypothesis if the null hypothesis is true.

The formula used to calculate the number of samples is:

$$n = \frac{S^2}{\Delta^2}\left(Z_{1-\alpha} + Z_{1-\beta}\right)^2 + 0.5Z_{1-\alpha}^2$$

where

n is the number of samples,
S is the estimated standard deviation of the measured values including analytical error,
Δ is the width of the gray region,
α is the acceptable probability of incorrectly concluding the site mean is less than the threshold,
β is the acceptable probability of incorrectly concluding the site mean exceeds the threshold,
$Z_{1-\alpha}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\alpha}$ is $1-\alpha$,
$Z_{1-\beta}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\beta}$ is $1-\beta$.

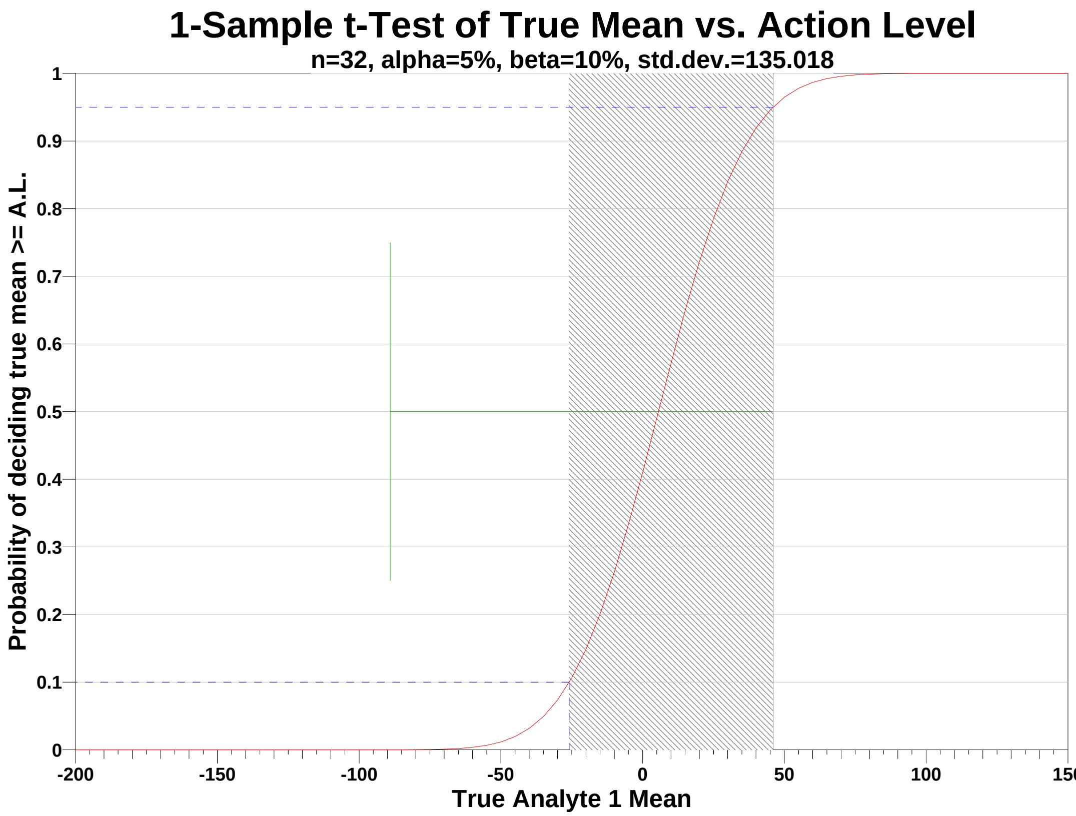
The values of these inputs that result in the calculated number of sampling locations are:

Analyte	n	Parameter					
		S	Δ	α	β	$Z_{1-\alpha}$ [a]	$Z_{1-\beta}$ [b]
Analyte 1	32	135.018	71.8857	0.05	0.1	1.64485	1.28155
Zinc	0	mg/kg	mg/kg				

[a] This value is automatically calculated by VSP based upon the user defined value of α.
[b] This value is automatically calculated by VSP based upon the user defined value of β.

The following figure is a performance goal diagram, described in EPA's QA/G-4 guidance (EPA, 2000) for Analyte 1, the driving analyte. It shows the probability of concluding the sample area is dirty on the vertical axis versus a range of possible true mean values for the site on the horizontal axis. This graph contains all of the inputs to the number of samples equation and pictorially represents the calculation.

The red vertical line is shown at the threshold (action limit) on the horizontal axis. The width of the gray shaded area is equal to Δ; the upper horizontal dashed blue line is positioned at 1-α on the vertical axis; the lower horizontal dashed blue line is positioned at β on the vertical axis. The vertical green line is positioned at one standard deviation below the threshold. The shape of the red curve corresponds to the estimates of variability. The calculated number of samples results in the curve that passes through the lower bound of Δ at β and the upper bound of Δ at 1-α. If any of the inputs change, the number of samples that result in the correct curve changes.



Statistical Assumptions

The assumptions associated with the formulas for computing the number of samples are:

1. the sample mean is normally distributed (this happens if the data are roughly symmetric or the sample size is more than 30; for extremely skewed data sets, additional samples may be required for the sample mean to be normally distributed),
2. the variance estimate, S^2, is reasonable and representative of the population being sampled,
3. the population values are not spatially or temporally correlated, and
4. the sampling locations will be selected probabilistically.

The first three assumptions will be assessed in a post data collection analysis. The last assumption is valid because the gridded sample locations were selected based on a random start.

Sensitivity Analysis
The sensitivity of the calculation of number of samples was explored by varying the standard deviation, lower bound of gray region (% of action level), beta (%), probability of mistakenly concluding that μ > action level and alpha (%), probability of mistakenly concluding that μ < action level. The following table shows the results of this analysis.

Number of Samples							
AL=46		**α=5**		**α=10**		**α=15**	
		s=270.036	**s=135.018**	**s=270.036**	**s=135.018**	**s=270.036**	**s=135.018**
LBGR=90	**β=5**	37296	9325	29513	7379	24776	6195
	β=10	29514	7380	22640	5661	18517	4630
	β=15	24777	6196	18517	4630	14808	3703
LBGR=80	**β=5**	9325	2333	7379	1846	6195	1549
	β=10	7380	1846	5661	1416	4630	1158
	β=15	6196	1550	4630	1159	3703	926
LBGR=70	**β=5**	4146	1038	3280	821	2754	689
	β=10	3281	822	2517	630	2058	515
	β=15	2755	690	2059	516	1646	412

s = Standard Deviation
LBGR = Lower Bound of Gray Region (% of Action Level)
β = Beta (%), Probability of mistakenly concluding that μ > action level
α = Alpha (%), Probability of mistakenly concluding that μ < action level
AL = Action Level (Threshold)

Cost of Sampling
The total cost of the completed sampling program depends on several cost inputs, some of which are fixed, and others that are based on the number of samples collected and measured. Based on the numbers of samples determined above, the estimated total cost of sampling and analysis at this site is $17,000.00, which averages out to a per sample cost of $531.25. The following table summarizes the inputs and resulting cost estimates.

COST INFORMATION			
Cost Details	**Per Analysis**	**Per Sample**	**32 Samples**
Field collection costs		$100.00	$3,200.00
Analytical costs	$400.00	$400.00	$12,800.00
Sum of Field & Analytical costs		**$500.00**	**$16,000.00**
Fixed planning and validation costs			$1,000.00
Total cost			**$17,000.00**

Data Analysis for Zinc
The following data points were entered by the user for analysis.

Zinc (mg/kg)										
Rank	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0	23.9	32.8	32.9	44	66.6	279	346			

SUMMARY STATISTICS for Zinc	
n	7

Min				23.9				
Max				346				
Range				322.1				
Mean				117.89				
Median				44				
Variance				18230				
StdDev				135.02				
Std Error				51.032				
Skewness				1.2754				
Interquartile Range				246.2				
Percentiles								
1%	**5%**	**10%**	**25%**	**50%**	**75%**	**90%**	**95%**	**99%**
23.9	23.9	23.9	32.8	44	279	346	346	346

Outlier Test
Dixon's extreme value test was performed to test whether the lowest value is a statistical outlier. The test was conducted at the 5% significance level.

Data should not be excluded from analysis solely on the basis of the results of this or any other statistical test. If any values are flagged as possible outliers, further investigation is recommended to determine whether there is a plausible explanation that justifies removing or replacing them.

DIXON'S OUTLIER TEST for Zinc	
Dixon Test Statistic	0
Dixon 5% Critical Value	0

The calculated test statistic does not exceed the critical value, so the test cannot reject the null hypothesis that there are no outliers in the data, and concludes that the minimum value 23.9 is not an outlier at the 5% significance level.

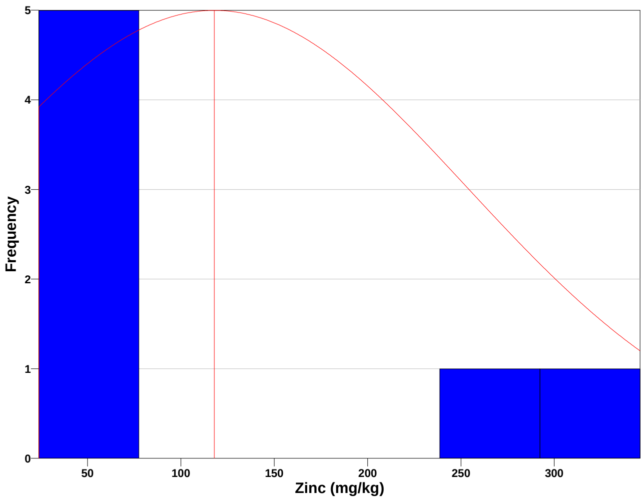
Data Plots for Zinc
Graphical displays of the data are shown below.

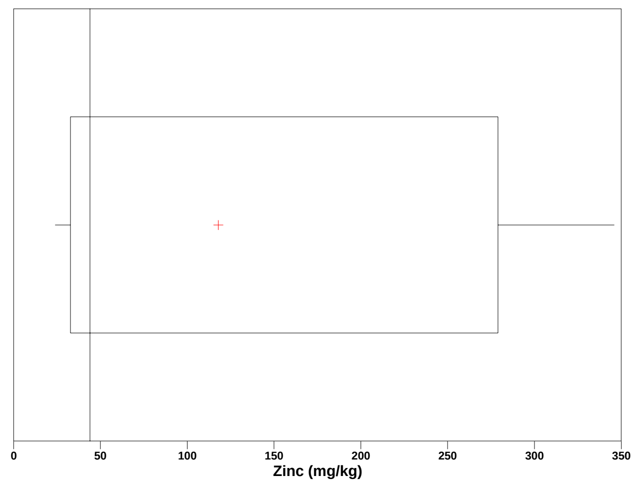
The Histogram is a plot of the fraction of the n observed data that fall within specified data “bins.” A histogram is generated by dividing the x axis (range of the observed data values) into "bins" and displaying the number of data in each bin as the height of a bar for the bin. The area of the bar is the fraction of the n data values that lie within the bin. The sum of the fractions for all bins equals one. A histogram is used to assess how the n data are distributed (spread) over their range of values. If the histogram is more or less symmetric and bell shaped, then the data may be normally distributed.

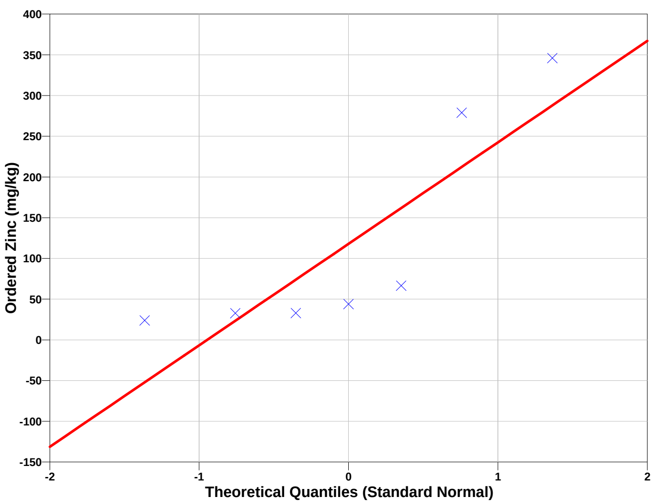
The Box and Whiskers plot is composed of a central box divided by a line, and with two lines extending out from the box, called the "whiskers". The line through the box is drawn at the median of the n data observed. The two ends of the box represent the 25^{th} and 75^{th} percentiles of the n data values, which are also called the lower and upper quartiles, respectively, of the data set. The sample mean (mean of the n data) is shown as a "+" sign. The upper whisker extends to the largest data value that is less than the upper quartile plus 1.5 times the interquartile range (upper quartile minus the lower quartile). The lower whisker extends to the smallest data value that is greater than the lower quartile minus 1.5 times the interquartile range. Extreme data values (greater or smaller than the ends of the whiskers) are plotted individually as blue Xs. A Box and Whiskers plot is used to assess the symmetry of the distribution of the data set. If the distribution is symmetrical, the box is divided into two equal halves by the median, the whiskers will be the same length, and the number of extreme data points will be distributed equally on either end of the plot.

The Q-Q plot graphs the quantiles of a set of n data against the quantiles of a specific distribution. We show here only the

Q-Q plot for an assumed normal distribution. The pth quantile of a distribution of data is the data value, x_p, for which a fraction p of the distribution is less than x_p. If the data plotted on the normal distribution Q-Q plot closely follow a straight line, even at the ends of the line, then the data may be assumed to be normally distributed. If the data points deviate substantially from a linear line, then the data are not normally distributed.







□□□□□For more information on these plots consult Guidance for Data Quality Assessment, EPA QA/G-9, pgs 2.3-1 through 2.3-12. (http://www.epa.gov/quality/qa-docs.html).

Tests for Zinc

A goodness-of-fit test was performed to test whether the data set had been drawn from an underlying normal distribution. The Shapiro-Wilk (SW) test was used to test the null hypothesis that the data are normally distributed. The test was conducted at the 5% significance level, i.e., the probability the test incorrectly rejects the null hypothesis was set at 0.05.

NORMAL DISTRIBUTION TEST	
Shapiro-Wilk Test Statistic	0.7173
Shapiro-Wilk 5% Critical Value	0.803

The calculated SW test statistic is less than the 5% Shapiro-Wilk critical value, so we can reject the hypothesis that the data are normal, or in other words the data do not appear to follow a normal distribution at the 5% level of significance. The Q-Q plot displayed above should be used to further assess the normality of the data.

Upper Confidence Limit on the True Mean

Two methods were used to compute the upper confidence limit (UCL) on the mean. The first is a parametric method that assumes a normal distribution. The second is the Chebyshev method, which requires no distributional assumption.

UCLs ON THE MEAN	
95% Parametric UCL	217.05
95% Non-Parametric (Chebyshev) UCL	340.33

Because the data do not appear to be normally distributed according to the goodness-of-fit test performed above, the non-parametric UCL (340.3) may be a more accurate upper confidence limit on the true mean.

One-Sample t-Test
A one-sample t-test was performed to compare the sample mean to the action level. The null hypothesis used is that the true mean equals or exceeds the action level (AL). The t-test was conducted at the % significance level. The sample value *t* was computed using the following equation:

$$t = \frac{\bar{x} - AL}{SE}$$

where
x is the sample mean of the n=7 data,
AL is the action level or threshold (46),
SE is the standard error = (standard deviation) / (square root of n).

This *t* was then compared with the critical value *t*, where *t* is the value of the t distribution with n-1=6 degrees of freedom for which the proportion of the distribution to the left of *t* is . The null hypothesis will be rejected if *t* < -*t*.

ONE-SAMPLE t-TEST		
t-statistic	**Critical Value *t***	**Null Hypothesis**
2.1141		Cannot Reject

The test did not reject the null hypothesis that the mean value at the site exceeds the threshold, therefore conclude the true mean exceeds the threshold.

Because the data do not appear to be normally distributed, the MARSSIM Sign Test might be preferred over the One Sample t-Test. The following table represents the results of the MARSSIM Sign Test using the current data:

MARSSIM Sign Test		
Test Statistic (S+)	**% Critical Value**	**Null Hypothesis**
0	6	Cannot Reject
Note: There may not be enough data to reject the null hypothesis (and conclude site is clean) with % confidence using the MARSSIM sign test.		

This report was automatically produced* by Visual Sample Plan (VSP) software version 6.3.
Software and documentation available at http://vsp.pnnl.gov

* - The report contents may have been modified or reformatted by end-user of software.

Appendix B

VSP Reports of Calculated Minimum Sample Quantity

Report 8

Area of Concern – 3

Minimum Sample Quantity Calculation for Subsurface Soil using Human Health Benchmarks

Systematic sampling locations for comparing a mean with a fixed threshold (parametric)

Summary
This report summarizes the sampling design, associated statistical assumptions, as well as general guidelines for conducting post-sampling data analysis. Sampling plan components presented here include how many sampling locations to choose and where within the sampling area to collect those samples. The type of medium to sample (i.e., soil, groundwater, etc.) and how to analyze the samples (in-situ, fixed laboratory, etc.) are addressed in other sections of the sampling plan.

The following table summarizes the sampling design. A figure that shows sampling locations in the field and a table that lists sampling location coordinates are also provided below.

SUMMARY OF SAMPLING DESIGN	
Primary Objective of Design	Compare a site mean to a fixed threshold
Type of Sampling Design	Parametric
Sample Placement (Location) in the Field	Systematic with a random start location
Working (Null) Hypothesis	The mean value at the site exceeds the threshold
Formula for calculating number of sampling locations	Student's t-test
Calculated total number of samples	12
Number of samples on map [a]	12
Number of selected sample areas [b]	1
Specified sampling area [c]	4421854.81 ft^2
Size of grid / Area of grid cell [d]	652.298 feet / 368488 ft^2
Grid pattern	Triangular
Total cost of sampling [e]	$7,000.00

[a] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.
[b] The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.
[c] The sampling area is the total surface area of the selected colored sample areas on the map of the site.
[d] Size of grid / Area of grid cell gives the linear and square dimensions of the grid used to systematically place samples.
[e] Including measurement analyses and fixed overhead costs. See the Cost of Sampling section for an explanation of the costs presented here.

Area: AOC-3 OW					
X Coord	Y Coord	Label	Value	Type	Historical
1411847.8987	17201925.0699			Systematic	
1412500.1971	17203054.8838			Systematic	
1412826.3463	17203619.7908			Systematic	
1412500.1971	17204184.6977			Systematic	
1413152.4954	17204184.6977			Systematic	
1412826.3463	17204749.6047			Systematic	
1413478.6446	17204749.6047			Systematic	
1414130.9430	17204749.6047			Systematic	
1412500.1971	17205314.5117			Systematic	
1413152.4954	17205314.5117			Systematic	
1413804.7938	17205314.5117			Systematic	
1412826.3463	17205879.4186			Systematic	

Primary Sampling Objective
The primary purpose of sampling at this site is to compare a mean value of a site with a fixed threshold. The working hypothesis (or 'null' hypothesis) is that the mean value at the site is equal to or exceeds the threshold. The alternative hypothesis is that the mean value is less than the threshold. VSP calculates the number of samples required to reject the null hypothesis in favor of the alternative hypothesis, given a selected sampling approach and inputs to the associated equation.

Selected Sampling Approach
A parametric systematic sampling approach with a random start was used to determine the number of samples and to specify sampling locations. A parametric formula was chosen because the conceptual model and historical information (e.g., historical data from this site or a very similar site) indicate that parametric assumptions are reasonable. These assumptions will be examined in post-sampling data analysis.

Both parametric and non-parametric approaches rely on assumptions about the population. However, non-parametric approaches typically require fewer assumptions and allow for more uncertainty about the statistical distribution of values at the site. The trade-off is that if the parametric assumptions are valid, the required number of samples is usually less than the number of samples required by non-parametric approaches.

Locating the sample points over a systematic grid with a random start ensures spatial coverage of the site. Statistical analyses of systematically collected data are valid if a random start to the grid is used. One disadvantage of systematically collected samples is that spatial variability or patterns may not be discovered if the grid spacing is large relative to the spatial patterns.

Number of Total Samples: Calculation Equation and Inputs
The equation used to calculate the number of samples is based on a Student's t-test. For this site, the null hypothesis is rejected in favor of the alternative hypothesis if the sample mean is sufficiently smaller than the threshold. The number of samples to collect is calculated so that 1) there will be a high probability ($1-\beta$) of rejecting the null hypothesis if the alternative hypothesis is true and 2) a low probability (α) of rejecting the null hypothesis if the null hypothesis is true.

The formula used to calculate the number of samples is:

$$n = \frac{S^2}{\Delta^2}\left(Z_{1-\alpha} + Z_{1-\beta}\right)^2 + 0.5Z_{1-\alpha}^2$$

where
n is the number of samples,
S is the estimated standard deviation of the measured values including analytical error,
Δ is the width of the gray region,
α is the acceptable probability of incorrectly concluding the site mean is less than the threshold,
β is the acceptable probability of incorrectly concluding the site mean exceeds the threshold,
$Z_{1-\alpha}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\alpha}$ is $1-\alpha$,
$Z_{1-\beta}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\beta}$ is $1-\beta$.

The values of these inputs that result in the calculated number of sampling locations are:

Analyte	n	Parameter					
		S	Δ	α	β	$Z_{1-\alpha}$ [a]	$Z_{1-\beta}$ [b]
Barium	12	68.7947 mg/kg	64.8143 mg/kg	0.05	0.1	1.64485	1.28155

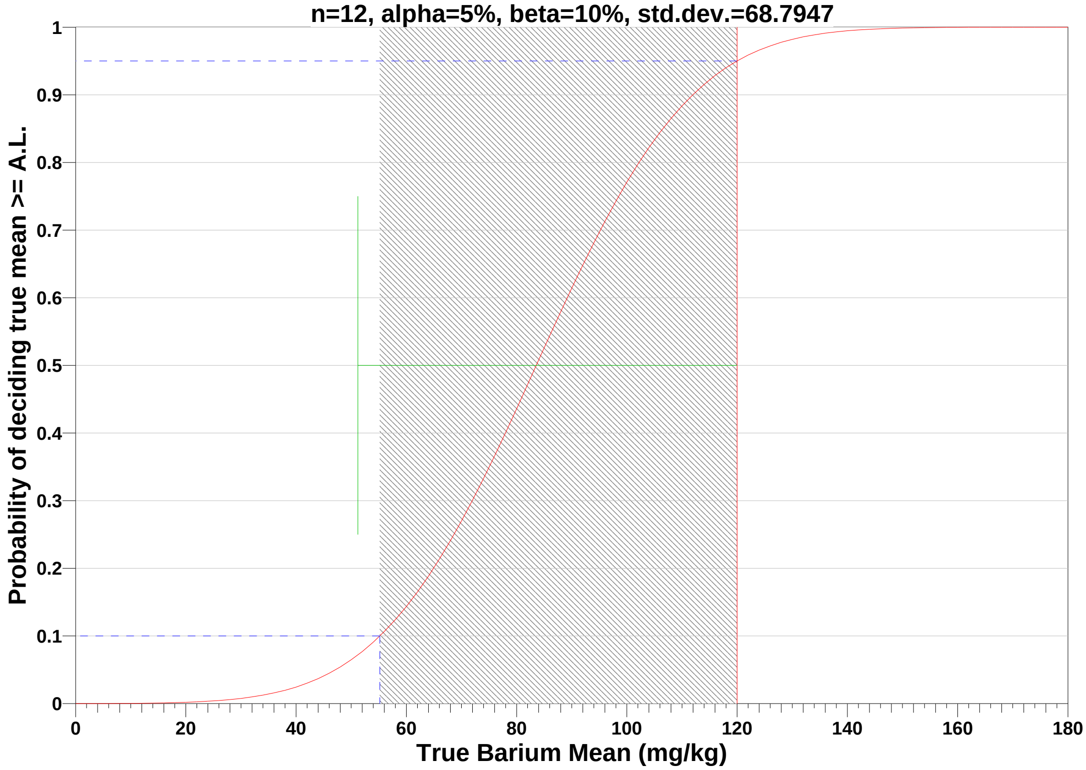
[a] This value is automatically calculated by VSP based upon the user defined value of α.
[b] This value is automatically calculated by VSP based upon the user defined value of β.

The following figure is a performance goal diagram, described in EPA's QA/G-4 guidance (EPA, 2000). It shows the probability of concluding the sample area is dirty on the vertical axis versus a range of possible true mean values for the site on the horizontal axis. This graph contains all of the inputs to the number of samples equation and pictorially represents the calculation.

The red vertical line is shown at the threshold (action limit) on the horizontal axis. The width of the gray shaded area is equal to Δ; the upper horizontal dashed blue line is positioned at $1-\alpha$ on the vertical axis; the lower horizontal dashed blue line is positioned at β on the vertical axis. The vertical green line is positioned at one standard deviation below the threshold. The shape of the red curve corresponds to the estimates of variability. The calculated number of samples results in the curve that passes through the lower bound of Δ at β and the upper bound of Δ at $1-\alpha$. If any of the inputs change, the number of samples that result in the correct curve changes.

1-Sample t-Test of True Mean vs. Action Level

n=12, alpha=5%, beta=10%, std.dev.=68.7947



Statistical Assumptions
The assumptions associated with the formulas for computing the number of samples are:

1. the sample mean is normally distributed (this happens if the data are roughly symmetric or the sample size is more than 30; for extremely skewed data sets, additional samples may be required for the sample mean to be normally distributed),
2. the variance estimate, S^2, is reasonable and representative of the population being sampled,
3. the population values are not spatially or temporally correlated, and
4. the sampling locations will be selected probabilistically.

The first three assumptions will be assessed in a post data collection analysis. The last assumption is valid because the gridded sample locations were selected based on a random start.

Sensitivity Analysis
The sensitivity of the calculation of number of samples was explored by varying the standard deviation, lower bound of gray region (% of action level), beta (%), probability of mistakenly concluding that μ > action level and alpha (%), probability of mistakenly concluding that μ < action level. The following table shows the results of this analysis.

Number of Samples							
AL=120		α=5		α=10		α=15	
		s=137.589	s=68.7947	s=137.589	s=68.7947	s=137.589	s=68.7947
LBGR=90	β=5	1425	358	1127	283	946	237
	β=10	1128	283	865	217	707	178
	β=15	947	238	708	178	566	142
LBGR=80	β=5	358	91	283	72	237	60
	β=10	283	72	217	55	178	45
	β=15	238	61	178	45	142	36
LBGR=70	β=5	160	41	126	33	106	27

	β=10	127	33	97	25	80	21
	β=15	107	28	80	21	64	17

s = Standard Deviation
LBGR = Lower Bound of Gray Region (% of Action Level)
β = Beta (%), Probability of mistakenly concluding that μ > action level
α = Alpha (%), Probability of mistakenly concluding that μ < action level
AL = Action Level (Threshold)

Cost of Sampling
The total cost of the completed sampling program depends on several cost inputs, some of which are fixed, and others that are based on the number of samples collected and measured. Based on the numbers of samples determined above, the estimated total cost of sampling and analysis at this site is $7,000.00, which averages out to a per sample cost of $583.33. The following table summarizes the inputs and resulting cost estimates.

COST INFORMATION			
Cost Details	**Per Analysis**	**Per Sample**	**12 Samples**
Field collection costs		$100.00	$1,200.00
Analytical costs	$400.00	$400.00	$4,800.00
Sum of Field & Analytical costs		**$500.00**	**$6,000.00**
Fixed planning and validation costs			$1,000.00
Total cost			**$7,000.00**

Data Analysis for Barium
The following data points were entered by the user for analysis.

Barium (mg/kg)										
Rank	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0	17.9	21.6	22.3	24.3	45.5	45.7	209			

SUMMARY STATISTICS for Barium								
n	7							
Min	17.9							
Max	209							
Range	191.1							
Mean	55.186							
Median	24.3							
Variance	4732.7							
StdDev	68.795							
Std Error	26.002							
Skewness	2.4958							
Interquartile Range	24.1							
Percentiles								
1%	**5%**	**10%**	**25%**	**50%**	**75%**	**90%**	**95%**	**99%**
17.9	17.9	17.9	21.6	24.3	45.7	209	209	209

Outlier Test
Dixon's extreme value test was performed to test whether the lowest value is a statistical outlier. The test was conducted at the 5% significance level.

Data should not be excluded from analysis solely on the basis of the results of this or any other statistical test. If any values are flagged as possible outliers, further investigation is recommended to determine whether there is a plausible explanation that justifies removing or replacing them.

DIXON'S OUTLIER TEST for Barium	
Dixon Test Statistic	0.019362
Dixon 5% Critical Value	0.507

The calculated test statistic does not exceed the critical value, so the test cannot reject the null hypothesis that there are no outliers in the data, and concludes that the minimum value 17.9 is not an outlier at the 5% significance level.

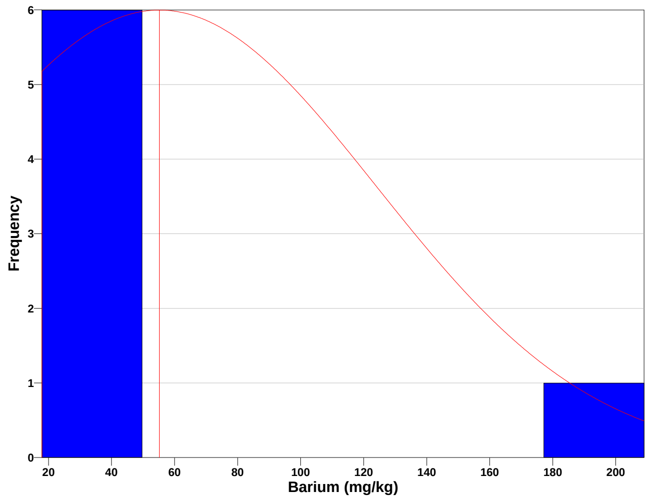
A normal distribution test indicated that the data do not appear to be normally distributed, so further investigation is recommended before using the results of this test.

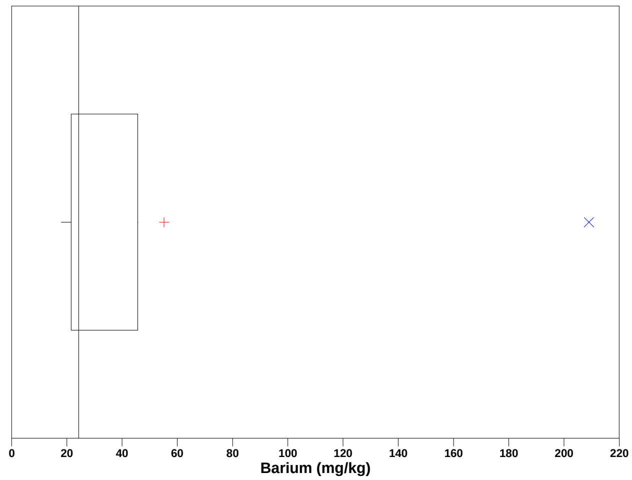
Data Plots for Barium
Graphical displays of the data are shown below.

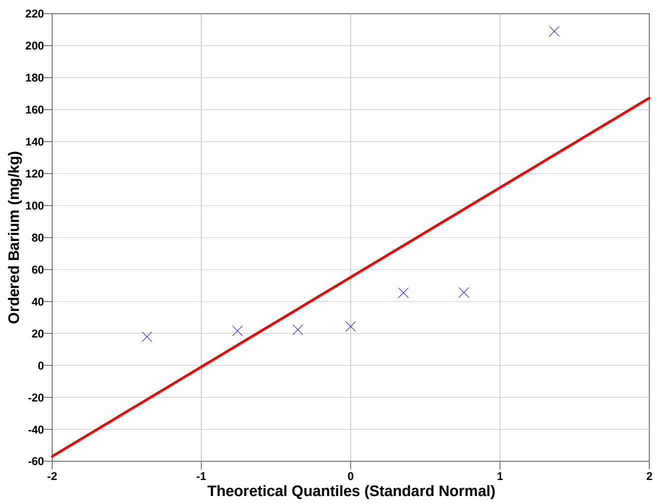
The Histogram is a plot of the fraction of the n observed data that fall within specified data “bins.” A histogram is generated by dividing the x axis (range of the observed data values) into "bins" and displaying the number of data in each bin as the height of a bar for the bin. The area of the bar is the fraction of the n data values that lie within the bin. The sum of the fractions for all bins equals one. A histogram is used to assess how the n data are distributed (spread) over their range of values. If the histogram is more or less symmetric and bell shaped, then the data may be normally distributed.

The Box and Whiskers plot is composed of a central box divided by a line, and with two lines extending out from the box, called the "whiskers". The line through the box is drawn at the median of the n data observed. The two ends of the box represent the 25^{th} and 75^{th} percentiles of the n data values, which are also called the lower and upper quartiles, respectively, of the data set. The sample mean (mean of the n data) is shown as a "+" sign. The upper whisker extends to the largest data value that is less than the upper quartile plus 1.5 times the interquartile range (upper quartile minus the lower quartile). The lower whisker extends to the smallest data value that is greater than the lower quartile minus 1.5 times the interquartile range. Extreme data values (greater or smaller than the ends of the whiskers) are plotted individually as blue Xs. A Box and Whiskers plot is used to assess the symmetry of the distribution of the data set. If the distribution is symmetrical, the box is divided into two equal halves by the median, the whiskers will be the same length, and the number of extreme data points will be distributed equally on either end of the plot.

The Q-Q plot graphs the quantiles of a set of n data against the quantiles of a specific distribution. We show here only the Q-Q plot for an assumed normal distribution. The p^{th} quantile of a distribution of data is the data value, x_p, for which a fraction p of the distribution is less than x_p. If the data plotted on the normal distribution Q-Q plot closely follow a straight line, even at the ends of the line, then the data may be assumed to be normally distributed. If the data points deviate substantially from a linear line, then the data are not normally distributed.







For more information on these plots consult Guidance for Data Quality Assessment, EPA QA/G-9, pgs 2.3-1 through 2.3-12. (http://www.epa.gov/quality/qa-docs.html).

Tests for Barium

A goodness-of-fit test was performed to test whether the data set had been drawn from an underlying normal distribution. The Shapiro-Wilk (SW) test was used to test the null hypothesis that the data are normally distributed. The test was conducted at the 5% significance level, i.e., the probability the test incorrectly rejects the null hypothesis was set at 0.05.

NORMAL DISTRIBUTION TEST	
Shapiro-Wilk Test Statistic	0.5921
Shapiro-Wilk 5% Critical Value	0.803

The calculated SW test statistic is less than the 5% Shapiro-Wilk critical value, so we can reject the hypothesis that the data are normal, or in other words the data do not appear to follow a normal distribution at the 5% level of significance. The Q-Q plot displayed above should be used to further assess the normality of the data.

Upper Confidence Limit on the True Mean

Two methods were used to compute the upper confidence limit (UCL) on the mean. The first is a parametric method that assumes a normal distribution. The second is the Chebyshev method, which requires no distributional assumption.

UCLs ON THE MEAN	
95% Parametric UCL	105.71

95% Non-Parametric (Chebyshev) UCL	168.53

Because the data do not appear to be normally distributed according to the goodness-of-fit test performed above, the non-parametric UCL (168.5) may be a more accurate upper confidence limit on the true mean.

One-Sample t-Test

A one-sample t-test was performed to compare the sample mean to the action level. The null hypothesis used is that the true mean equals or exceeds the action level (AL). The t-test was conducted at the 5% significance level. The sample value *t* was computed using the following equation:

$$t = \frac{\bar{x} - AL}{SE}$$

where

x is the sample mean of the n=7 data,

AL is the action level or threshold (120),

SE is the standard error = (standard deviation) / (square root of n).

This t was then compared with the critical value $t_{0.95}$, where $t_{0.95}$ is the value of the t distribution with n-1=6 degrees of freedom for which the proportion of the distribution to the left of $t_{0.95}$ is 0.95. The null hypothesis will be rejected if $t < -t_{0.95}$.

ONE-SAMPLE t-TEST		
t-statistic	**Critical Value $t_{0.95}$**	**Null Hypothesis**
-2.4927	1.9432	Reject

The test rejected the null hypothesis that the mean value at the site exceeds the threshold, therefore conclude the true mean is less than the threshold.

Because the data do not appear to be normally distributed, the MARSSIM Sign Test might be preferred over the One Sample t-Test. The following table represents the results of the MARSSIM Sign Test using the current data:

MARSSIM Sign Test		
Test Statistic (S+)	**95% Critical Value**	**Null Hypothesis**
6	6	Cannot Reject
Note: There may not be enough data to reject the null hypothesis (and conclude site is clean) with 95% confidence using the MARSSIM sign test.		

Appendix B

VSP Reports of Calculated Minimum Sample Quantity

Report 9

Area of Concern – 3

Minimum Sample Quantity Calculation for Subsurface Soil using Ecological Benchmarks

Systematic sampling locations for comparing a mean with a fixed threshold (parametric)

Summary

This report summarizes the sampling design, associated statistical assumptions, as well as general guidelines for conducting post-sampling data analysis. Sampling plan components presented here include how many sampling locations to choose and where within the sampling area to collect those samples. The type of medium to sample (i.e., soil, groundwater, etc.) and how to analyze the samples (in-situ, fixed laboratory, etc.) are addressed in other sections of the sampling plan.

The following table summarizes the sampling design. A figure that shows sampling locations in the field and a table that lists sampling location coordinates are also provided below.

SUMMARY OF SAMPLING DESIGN	
Primary Objective of Design	Compare a site mean to a fixed threshold
Type of Sampling Design	Parametric
Sample Placement (Location) in the Field	Systematic with a random start location
Working (Null) Hypothesis	The mean value at the site exceeds the threshold
Formula for calculating number of sampling locations	Student's t-test
Calculated total number of samples	4
Number of samples on map [a]	4
Number of selected sample areas [b]	1
Specified sampling area [c]	4421854.81 ft^2
Size of grid / Area of grid cell [d]	1129.81 feet / 1.10546e+006 ft^2
Grid pattern	Triangular
Total cost of sampling [e]	$3,000.00

[a] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.
[b] The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.
[c] The sampling area is the total surface area of the selected colored sample areas on the map of the site.
[d] Size of grid / Area of grid cell gives the linear and square dimensions of the grid used to systematically place samples.
[e] Including measurement analyses and fixed overhead costs. See the Cost of Sampling section for an explanation of the costs presented here.

Area: AOC-3 OW					
X Coord	**Y Coord**	**Label**	**Value**	**Type**	**Historical**
1413007.2712	17203062.9658			Systematic	
1413572.1782	17204041.4134			Systematic	
1413007.2712	17205019.8610			Systematic	
1414137.0852	17205019.8610			Systematic	

Primary Sampling Objective
The primary purpose of sampling at this site is to compare a mean value of a site with a fixed threshold. The working hypothesis (or 'null' hypothesis) is that the mean value at the site is equal to or exceeds the threshold. The alternative hypothesis is that the mean value is less than the threshold. VSP calculates the number of samples required to reject the null hypothesis in favor of the alternative hypothesis, given a selected sampling approach and inputs to the associated equation.

Selected Sampling Approach
A parametric systematic sampling approach with a random start was used to determine the number of samples and to specify sampling locations. A parametric formula was chosen because the conceptual model and historical information (e.g., historical data from this site or a very similar site) indicate that parametric assumptions are reasonable. These assumptions will be examined in post-sampling data analysis.

Both parametric and non-parametric approaches rely on assumptions about the population. However, non-parametric approaches typically require fewer assumptions and allow for more uncertainty about the statistical distribution of values at the site. The trade-off is that if the parametric assumptions are valid, the required number of samples is usually less than the number of samples required by non-parametric approaches.

Locating the sample points over a systematic grid with a random start ensures spatial coverage of the site. Statistical analyses of systematically collected data are valid if a random start to the grid is used. One disadvantage of systematically collected samples is that spatial variability or patterns may not be discovered if the grid spacing is large relative to the spatial patterns.

Number of Total Samples: Calculation Equation and Inputs
The equation used to calculate the number of samples is based on a Student's t-test. For this site, the null hypothesis is rejected in favor of the alternative hypothesis if the sample mean is sufficiently smaller than the threshold. The number of

samples to collect is calculated so that 1) there will be a high probability (1-β) of rejecting the null hypothesis if the alternative hypothesis is true and 2) a low probability (α) of rejecting the null hypothesis if the null hypothesis is true.

The formula used to calculate the number of samples is:

$$n = \frac{S^2}{\Delta^2}\left(Z_{1-\alpha} + Z_{1-\beta}\right)^2 + 0.5Z_{1-\alpha}^2$$

where
n is the number of samples,
S is the estimated standard deviation of the measured values including analytical error,
Δ is the width of the gray region,
α is the acceptable probability of incorrectly concluding the site mean is less than the threshold,
β is the acceptable probability of incorrectly concluding the site mean exceeds the threshold,
$Z_{1-\alpha}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\alpha}$ is 1-α,
$Z_{1-\beta}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\beta}$ is 1-β.

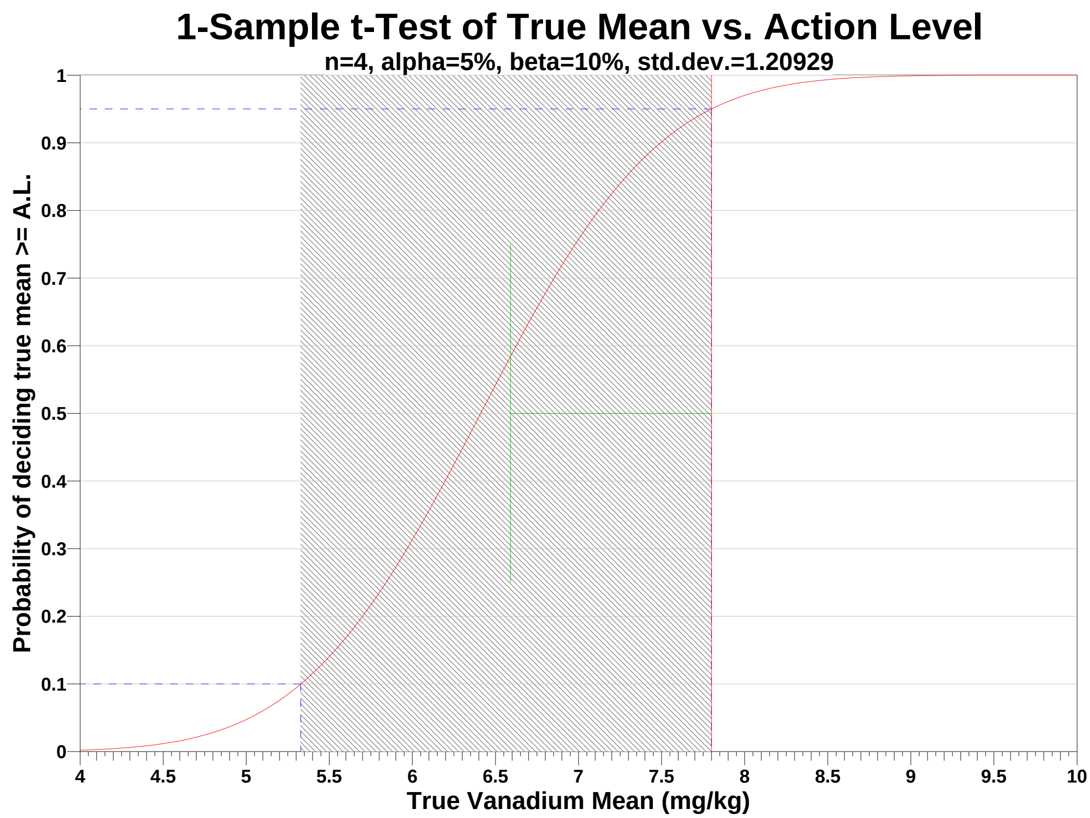
The values of these inputs that result in the calculated number of sampling locations are:

Analyte	n	Parameter					
		S	Δ	α	β	$Z_{1-\alpha}$ [a]	$Z_{1-\beta}$ [b]
Vanadium	4	1.20929 mg/kg	2.47143 mg/kg	0.05	0.1	1.64485	1.28155

[a] This value is automatically calculated by VSP based upon the user defined value of α.
[b] This value is automatically calculated by VSP based upon the user defined value of β.

The following figure is a performance goal diagram, described in EPA's QA/G-4 guidance (EPA, 2000). It shows the probability of concluding the sample area is dirty on the vertical axis versus a range of possible true mean values for the site on the horizontal axis. This graph contains all of the inputs to the number of samples equation and pictorially represents the calculation.

The red vertical line is shown at the threshold (action limit) on the horizontal axis. The width of the gray shaded area is equal to Δ; the upper horizontal dashed blue line is positioned at 1-α on the vertical axis; the lower horizontal dashed blue line is positioned at β on the vertical axis. The vertical green line is positioned at one standard deviation below the threshold. The shape of the red curve corresponds to the estimates of variability. The calculated number of samples results in the curve that passes through the lower bound of Δ at β and the upper bound of Δ at 1-α. If any of the inputs change, the number of samples that result in the correct curve changes.



Statistical Assumptions
The assumptions associated with the formulas for computing the number of samples are:

1. the sample mean is normally distributed (this happens if the data are roughly symmetric or the sample size is more than 30; for extremely skewed data sets, additional samples may be required for the sample mean to be normally distributed),
2. the variance estimate, S^2, is reasonable and representative of the population being sampled,
3. the population values are not spatially or temporally correlated, and
4. the sampling locations will be selected probabilistically.

The first three assumptions will be assessed in a post data collection analysis. The last assumption is valid because the gridded sample locations were selected based on a random start.

Sensitivity Analysis
The sensitivity of the calculation of number of samples was explored by varying the standard deviation, lower bound of gray region (% of action level), beta (%), probability of mistakenly concluding that μ > action level and alpha (%), probability of mistakenly concluding that μ < action level. The following table shows the results of this analysis.

Number of Samples							
AL=7.8		α=5		α=10		α=15	
		s=2.41858	s=1.20929	s=2.41858	s=1.20929	s=2.41858	s=1.20929
LBGR=90	β=5	106	28	84	22	70	18
	β=10	84	22	64	17	53	14
	β=15	71	19	53	14	42	11
LBGR=80	β=5	28	8	22	6	18	5
	β=10	22	7	17	5	14	4
	β=15	19	6	14	5	11	4
LBGR=70	β=5	13	5	10	4	9	3

	β=10	11	4	8	3	7	2
	β=15	10	4	7	3	6	2

s = Standard Deviation
LBGR = Lower Bound of Gray Region (% of Action Level)
β = Beta (%), Probability of mistakenly concluding that μ > action level
α = Alpha (%), Probability of mistakenly concluding that μ < action level
AL = Action Level (Threshold)

Cost of Sampling
The total cost of the completed sampling program depends on several cost inputs, some of which are fixed, and others that are based on the number of samples collected and measured. Based on the numbers of samples determined above, the estimated total cost of sampling and analysis at this site is $3,000.00, which averages out to a per sample cost of $750.00. The following table summarizes the inputs and resulting cost estimates.

COST INFORMATION			
Cost Details	**Per Analysis**	**Per Sample**	**4 Samples**
Field collection costs		$100.00	$400.00
Analytical costs	$400.00	$400.00	$1,600.00
Sum of Field & Analytical costs		**$500.00**	**$2,000.00**
Fixed planning and validation costs			$1,000.00
Total cost			**$3,000.00**

Data Analysis for Vanadium
The following data points were entered by the user for analysis.

Vanadium (mg/kg)										
Rank	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0	4.4	4.5	4.6	5.1	5.3	5.5	7.9			

SUMMARY STATISTICS for Vanadium								
n	7							
Min	4.4							
Max	7.9							
Range	3.5							
Mean	5.3286							
Median	5.1							
Variance	1.4624							
StdDev	1.2093							
Std Error	0.45707							
Skewness	2.0108							
Interquartile Range	1							
Percentiles								
1%	**5%**	**10%**	**25%**	**50%**	**75%**	**90%**	**95%**	**99%**
4.4	4.4	4.4	4.5	5.1	5.5	7.9	7.9	7.9

Outlier Test
Dixon's extreme value test was performed to test whether the lowest value is a statistical outlier. The test was conducted at the 5% significance level.

Data should not be excluded from analysis solely on the basis of the results of this or any other statistical test. If any values are flagged as possible outliers, further investigation is recommended to determine whether there is a plausible explanation that justifies removing or replacing them.

DIXON'S OUTLIER TEST for Vanadium	
Dixon Test Statistic	0.028571
Dixon 5% Critical Value	0.507

The calculated test statistic does not exceed the critical value, so the test cannot reject the null hypothesis that there are no outliers in the data, and concludes that the minimum value 4.4 is not an outlier at the 5% significance level.

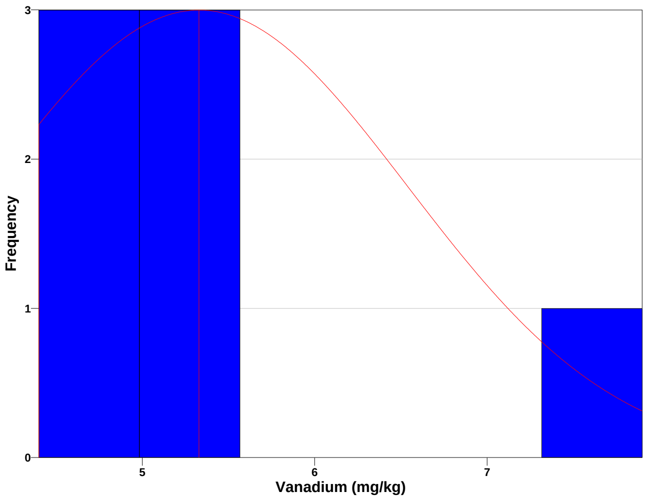
A normal distribution test indicated that the data do not appear to be normally distributed, so further investigation is recommended before using the results of this test.

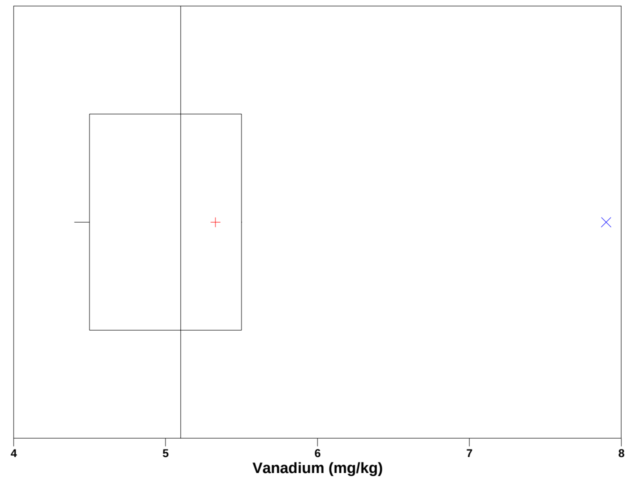
Data Plots for Vanadium
Graphical displays of the data are shown below.

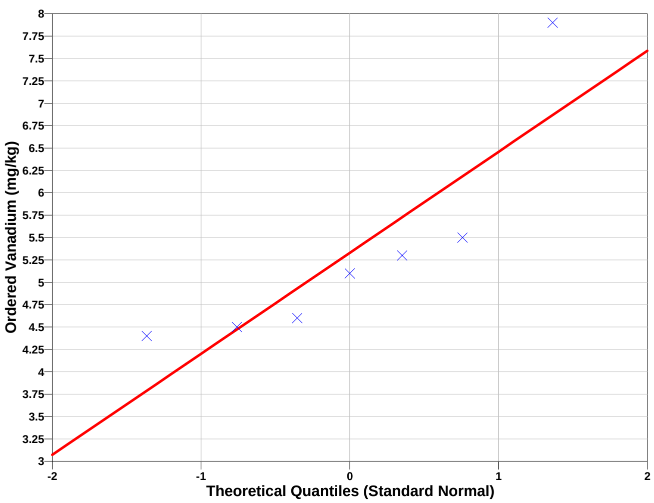
The Histogram is a plot of the fraction of the n observed data that fall within specified data “bins.” A histogram is generated by dividing the x axis (range of the observed data values) into "bins" and displaying the number of data in each bin as the height of a bar for the bin. The area of the bar is the fraction of the n data values that lie within the bin. The sum of the fractions for all bins equals one. A histogram is used to assess how the n data are distributed (spread) over their range of values. If the histogram is more or less symmetric and bell shaped, then the data may be normally distributed.

The Box and Whiskers plot is composed of a central box divided by a line, and with two lines extending out from the box, called the "whiskers". The line through the box is drawn at the median of the n data observed. The two ends of the box represent the 25th and 75th percentiles of the n data values, which are also called the lower and upper quartiles, respectively, of the data set. The sample mean (mean of the n data) is shown as a "+" sign. The upper whisker extends to the largest data value that is less than the upper quartile plus 1.5 times the interquartile range (upper quartile minus the lower quartile). The lower whisker extends to the smallest data value that is greater than the lower quartile minus 1.5 times the interquartile range. Extreme data values (greater or smaller than the ends of the whiskers) are plotted individually as blue Xs. A Box and Whiskers plot is used to assess the symmetry of the distribution of the data set. If the distribution is symmetrical, the box is divided into two equal halves by the median, the whiskers will be the same length, and the number of extreme data points will be distributed equally on either end of the plot.

The Q-Q plot graphs the quantiles of a set of n data against the quantiles of a specific distribution. We show here only the Q-Q plot for an assumed normal distribution. The pth quantile of a distribution of data is the data value, x_n, for which a fraction p of the distribution is less than x_n. If the data plotted on the normal distribution Q-Q plot closely follow a straight line, even at the ends of the line, then the data may be assumed to be normally distributed. If the data points deviate substantially from a linear line, then the data are not normally distributed.







For more information on these plots consult Guidance for Data Quality Assessment, EPA QA/G-9, pgs 2.3-1 through 2.3-12. (http://www.epa.gov/quality/qa-docs.html).

Tests for Vanadium

A goodness-of-fit test was performed to test whether the data set had been drawn from an underlying normal distribution. The Shapiro-Wilk (SW) test was used to test the null hypothesis that the data are normally distributed. The test was conducted at the 5% significance level, i.e., the probability the test incorrectly rejects the null hypothesis was set at 0.05.

NORMAL DISTRIBUTION TEST	
Shapiro-Wilk Test Statistic	0.7602
Shapiro-Wilk 5% Critical Value	0.803

The calculated SW test statistic is less than the 5% Shapiro-Wilk critical value, so we can reject the hypothesis that the data are normal, or in other words the data do not appear to follow a normal distribution at the 5% level of significance. The Q-Q plot displayed above should be used to further assess the normality of the data.

Upper Confidence Limit on the True Mean

Two methods were used to compute the upper confidence limit (UCL) on the mean. The first is a parametric method that assumes a normal distribution. The second is the Chebyshev method, which requires no distributional assumption.

UCLs ON THE MEAN	
95% Parametric UCL	6.2167

95% Non-Parametric (Chebyshev) UCL	7.3209

Because the data do not appear to be normally distributed according to the goodness-of-fit test performed above, the non-parametric UCL (7.321) may be a more accurate upper confidence limit on the true mean.

One-Sample t-Test

A one-sample t-test was performed to compare the sample mean to the action level. The null hypothesis used is that the true mean equals or exceeds the action level (AL). The t-test was conducted at the 5% significance level. The sample value *t* was computed using the following equation:

$$t = \frac{\bar{x} - AL}{SE}$$

where

x is the sample mean of the n=7 data,

AL is the action level or threshold (7.8),

SE is the standard error = (standard deviation) / (square root of n).

This t was then compared with the critical value $t_{0.95}$, where $t_{0.95}$ is the value of the t distribution with n-1=6 degrees of freedom for which the proportion of the distribution to the left of $t_{0.95}$ is 0.95. The null hypothesis will be rejected if $t < -t_{0.95}$.

ONE-SAMPLE t-TEST		
t-statistic	**Critical Value $t_{0.95}$**	**Null Hypothesis**
-5.4071	1.9432	Reject

The test rejected the null hypothesis that the mean value at the site exceeds the threshold, therefore conclude the true mean is less than the threshold.

Because the data do not appear to be normally distributed, the MARSSIM Sign Test might be preferred over the One Sample t-Test. The following table represents the results of the MARSSIM Sign Test using the current data:

MARSSIM Sign Test		
Test Statistic (S+)	**95% Critical Value**	**Null Hypothesis**
6	6	Cannot Reject
Note: There may not be enough data to reject the null hypothesis (and conclude site is clean) with 95% confidence using the MARSSIM sign test.		

This report was automatically produced* by Visual Sample Plan (VSP) software version 6.3.

Software and documentation available at http://vsp.pnnl.gov

* - The report contents may have been modified or reformatted by end-user of software.

Appendix B

VSP Reports of Calculated Minimum Sample Quantity

Report 10

Area of Concern – 3

Minimum Sample Quantity Calculation for Surface Water using Human Health Benchmarks

Systematic sampling locations for comparing a mean with a fixed threshold (parametric)

Summary

This report summarizes the sampling design, associated statistical assumptions, as well as general guidelines for conducting post-sampling data analysis. Sampling plan components presented here include how many sampling locations to choose and where within the sampling area to collect those samples. The type of medium to sample (i.e., soil, groundwater, etc.) and how to analyze the samples (in-situ, fixed laboratory, etc.) are addressed in other sections of the sampling plan.

The following table summarizes the sampling design. A figure that shows sampling locations in the field and a table that lists sampling location coordinates are also provided below.

SUMMARY OF SAMPLING DESIGN	
Primary Objective of Design	Compare a site mean to a fixed threshold
Type of Sampling Design	Parametric
Sample Placement (Location) in the Field	Systematic with a random start location
Working (Null) Hypothesis	The mean value at the site exceeds the threshold
Formula for calculating number of sampling locations	Student's t-test
Calculated total number of samples	36
Number of samples on map [a]	36
Number of selected sample areas [b]	1
Specified sampling area [c]	1874440.39 ft^2
Size of grid / Area of grid cell [d]	245.199 feet / 52067.8 ft^2
Grid pattern	Triangular
Total cost of sampling [e]	$19,000.00

[a] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.
[b] The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.
[c] The sampling area is the total surface area of the selected colored sample areas on the map of the site.
[d] Size of grid / Area of grid cell gives the linear and square dimensions of the grid used to systematically place samples.
[e] Including measurement analyses and fixed overhead costs. See the Cost of Sampling section for an explanation of the costs presented here.

Area: AOC-3 IW					
X Coord	Y Coord	Label	Value	Type	Historical
1411576.7608	17202075.6959			Systematic	
1411821.9601	17202075.6959			Systematic	
1411699.3605	17202288.0448			Systematic	
1411944.5598	17202288.0448			Systematic	
1412434.9584	17202288.0448			Systematic	
1411821.9601	17202500.3936			Systematic	
1412312.3587	17202500.3936			Systematic	
1412557.5581	17202500.3936			Systematic	
1411944.5598	17202712.7424			Systematic	
1412189.7591	17202712.7424			Systematic	
1412434.9584	17202712.7424			Systematic	
1412312.3587	17202925.0913			Systematic	
1412067.1594	17203349.7889			Systematic	
1412312.3587	17203349.7889			Systematic	
1412434.9584	17203562.1378			Systematic	
1412312.3587	17203774.4866			Systematic	
1412557.5581	17203774.4866			Systematic	
1412802.7574	17203774.4866			Systematic	
1412434.9584	17203986.8355			Systematic	
1412680.1577	17203986.8355			Systematic	
1412925.3570	17203986.8355			Systematic	
1412802.7574	17204199.1843			Systematic	

1413783.5546	17204199.1843			Systematic	
1414028.7539	17204199.1843			Systematic	
1412925.3570	17204411.5331			Systematic	
1414151.3536	17204411.5331			Systematic	
1413047.9567	17204623.8820			Systematic	
1414028.7539	17204623.8820			Systematic	
1414273.9533	17204623.8820			Systematic	
1413170.5563	17204836.2308			Systematic	
1413906.1543	17204836.2308			Systematic	
1413047.9567	17205048.5796			Systematic	
1413293.1560	17205048.5796			Systematic	
1413783.5546	17205048.5796			Systematic	
1412680.1577	17205260.9285			Systematic	
1412802.7574	17205473.2773			Systematic	

Primary Sampling Objective
The primary purpose of sampling at this site is to compare a mean value of a site with a fixed threshold. The working hypothesis (or 'null' hypothesis) is that the mean value at the site is equal to or exceeds the threshold. The alternative hypothesis is that the mean value is less than the threshold. VSP calculates the number of samples required to reject the null hypothesis in favor of the alternative hypothesis, given a selected sampling approach and inputs to the associated equation.

Selected Sampling Approach
A parametric systematic sampling approach with a random start was used to determine the number of samples and to specify sampling locations. A parametric formula was chosen because the conceptual model and historical information (e.g., historical data from this site or a very similar site) indicate that parametric assumptions are reasonable. These assumptions will be examined in post-sampling data analysis.

Both parametric and non-parametric approaches rely on assumptions about the population. However, non-parametric approaches typically require fewer assumptions and allow for more uncertainty about the statistical distribution of values at the site. The trade-off is that if the parametric assumptions are valid, the required number of samples is usually less than the number of samples required by non-parametric approaches.

Locating the sample points over a systematic grid with a random start ensures spatial coverage of the site. Statistical analyses of systematically collected data are valid if a random start to the grid is used. One disadvantage of systematically collected samples is that spatial variability or patterns may not be discovered if the grid spacing is large relative to the spatial patterns.

Number of Total Samples: Calculation Equation and Inputs
The equation used to calculate the number of samples is based on a Student's t-test. For this site, the null hypothesis is rejected in favor of the alternative hypothesis if the sample mean is sufficiently smaller than the threshold. The number of samples to collect is calculated so that 1) there will be a high probability ($1-\beta$) of rejecting the null hypothesis if the alternative hypothesis is true and 2) a low probability (α) of rejecting the null hypothesis if the null hypothesis is true.

The formula used to calculate the number of samples is:

$$n = \frac{S^2}{\Delta^2}\left(Z_{1-\alpha} + Z_{1-\beta}\right)^2 + 0.5Z^2_{1-\alpha}$$

where
n is the number of samples,
S is the estimated standard deviation of the measured values including analytical error,
Δ is the width of the gray region,

α is the acceptable probability of incorrectly concluding the site mean is less than the threshold,
β is the acceptable probability of incorrectly concluding the site mean exceeds the threshold,
$Z_{1-\alpha}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\alpha}$ is $1-\alpha$,
$Z_{1-\beta}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\beta}$ is $1-\beta$.

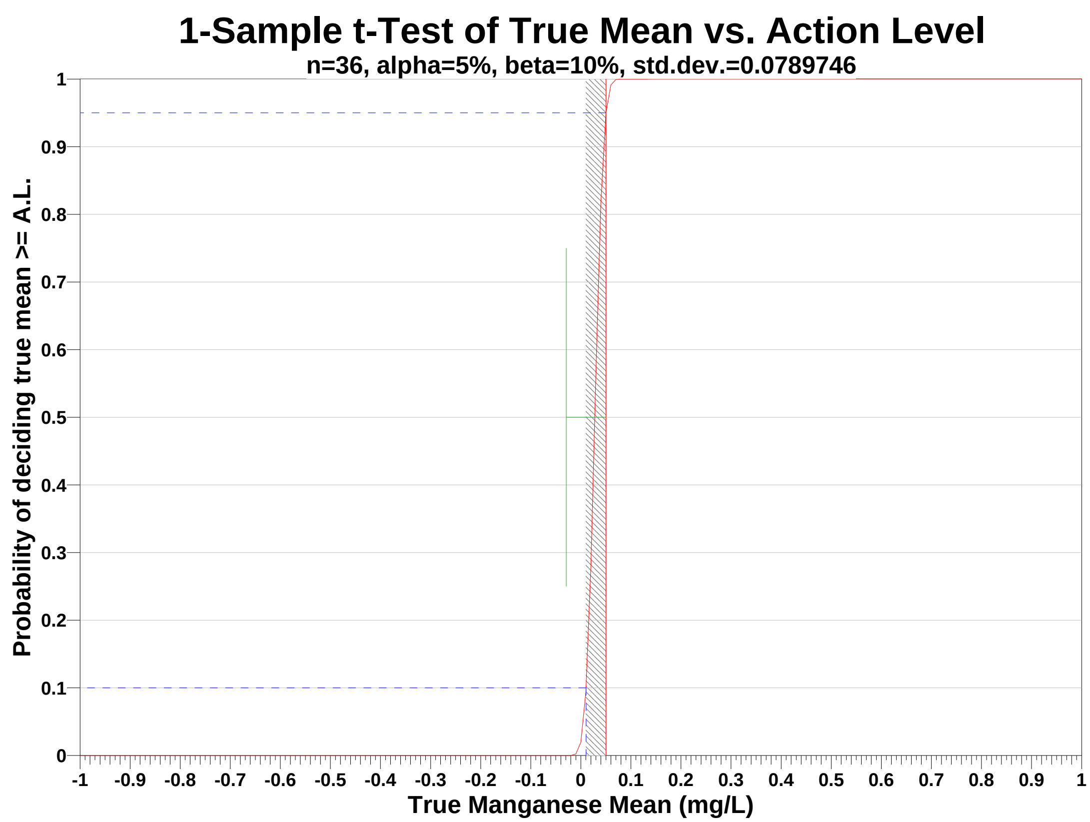
The values of these inputs that result in the calculated number of sampling locations are:

Analyte	n	Parameter					
		S	Δ	α	β	$Z_{1-\alpha}$ [a]	$Z_{1-\beta}$ [b]
Manganese	36	0.0789746 mg/L	0.0394873 mg/L	0.05	0.1	1.64485	1.28155

[a] This value is automatically calculated by VSP based upon the user defined value of α.
[b] This value is automatically calculated by VSP based upon the user defined value of β.

The following figure is a performance goal diagram, described in EPA's QA/G-4 guidance (EPA, 2000). It shows the probability of concluding the sample area is dirty on the vertical axis versus a range of possible true mean values for the site on the horizontal axis. This graph contains all of the inputs to the number of samples equation and pictorially represents the calculation.

The red vertical line is shown at the threshold (action limit) on the horizontal axis. The width of the gray shaded area is equal to Δ; the upper horizontal dashed blue line is positioned at $1-\alpha$ on the vertical axis; the lower horizontal dashed blue line is positioned at β on the vertical axis. The vertical green line is positioned at one standard deviation below the threshold. The shape of the red curve corresponds to the estimates of variability. The calculated number of samples results in the curve that passes through the lower bound of Δ at β and the upper bound of Δ at $1-\alpha$. If any of the inputs change, the number of samples that result in the correct curve changes.



Statistical Assumptions
The assumptions associated with the formulas for computing the number of samples are:
1. the sample mean is normally distributed (this happens if the data are roughly symmetric or the sample size is more than 30; for extremely skewed data sets, additional samples may be required for the sample mean to be normally

distributed),
2. the variance estimate, S^2, is reasonable and representative of the population being sampled,
3. the population values are not spatially or temporally correlated, and
4. the sampling locations will be selected probabilistically.

The first three assumptions will be assessed in a post data collection analysis. The last assumption is valid because the gridded sample locations were selected based on a random start.

Sensitivity Analysis
The sensitivity of the calculation of number of samples was explored by varying the standard deviation, lower bound of gray region (% of action level), beta (%), probability of mistakenly concluding that μ > action level and alpha (%), probability of mistakenly concluding that μ < action level. The following table shows the results of this analysis.

Number of Samples							
AL=0.05		**α=5**		**α=10**		**α=15**	
		s=0.157949	**s=0.0789746**	**s=0.157949**	**s=0.0789746**	**s=0.157949**	**s=0.0789746**
LBGR=90	**β=5**	10801	2702	8547	2138	7175	1795
	β=10	8548	2138	6557	1640	5363	1342
	β=15	7176	1795	5363	1342	4289	1073
LBGR=80	**β=5**	2702	677	2138	535	1795	449
	β=10	2138	536	1640	411	1342	336
	β=15	1795	450	1342	336	1073	269
LBGR=70	**β=5**	1202	302	951	239	798	200
	β=10	951	239	730	183	597	150
	β=15	799	201	597	150	477	120

s = Standard Deviation
LBGR = Lower Bound of Gray Region (% of Action Level)
β = Beta (%), Probability of mistakenly concluding that μ > action level
α = Alpha (%), Probability of mistakenly concluding that μ < action level
AL = Action Level (Threshold)

Cost of Sampling
The total cost of the completed sampling program depends on several cost inputs, some of which are fixed, and others that are based on the number of samples collected and measured. Based on the numbers of samples determined above, the estimated total cost of sampling and analysis at this site is $19,000.00, which averages out to a per sample cost of $527.78. The following table summarizes the inputs and resulting cost estimates.

COST INFORMATION			
Cost Details	**Per Analysis**	**Per Sample**	**36 Samples**
Field collection costs		$100.00	$3,600.00
Analytical costs	$400.00	$400.00	$14,400.00
Sum of Field & Analytical costs		**$500.00**	**$18,000.00**
Fixed planning and validation costs			$1,000.00
Total cost			**$19,000.00**

Data Analysis for Manganese
The following data points were entered by the user for analysis.

Manganese (mg/L)

Rank	1	2	3	4	5	6	7	8	9	10
0	0.0069	0.008	0.014	0.0145	0.0214	0.151	0.194			

SUMMARY STATISTICS for Manganese								
n	7							
Min	0.0069							
Max	0.194							
Range	0.1871							
Mean	0.058543							
Median	0.0145							
Variance	0.006237							
StdDev	0.078975							
Std Error	0.02985							
Skewness	1.3188							
Interquartile Range	0.143							
Percentiles								
1%	5%	10%	25%	50%	75%	90%	95%	99%
0.0069	0.0069	0.0069	0.008	0.0145	0.151	0.194	0.194	0.194

Outlier Test
Dixon's extreme value test was performed to test whether the lowest value is a statistical outlier. The test was conducted at the 5% significance level.

Data should not be excluded from analysis solely on the basis of the results of this or any other statistical test. If any values are flagged as possible outliers, further investigation is recommended to determine whether there is a plausible explanation that justifies removing or replacing them.

DIXON'S OUTLIER TEST for Manganese	
Dixon Test Statistic	0.0058792
Dixon 5% Critical Value	0.507

The calculated test statistic does not exceed the critical value, so the test cannot reject the null hypothesis that there are no outliers in the data, and concludes that the minimum value 0.0069 is not an outlier at the 5% significance level.

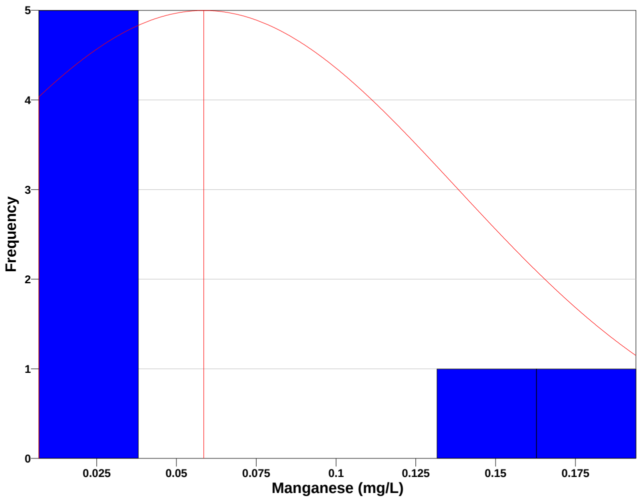
A normal distribution test indicated that the data do not appear to be normally distributed, so further investigation is recommended before using the results of this test.

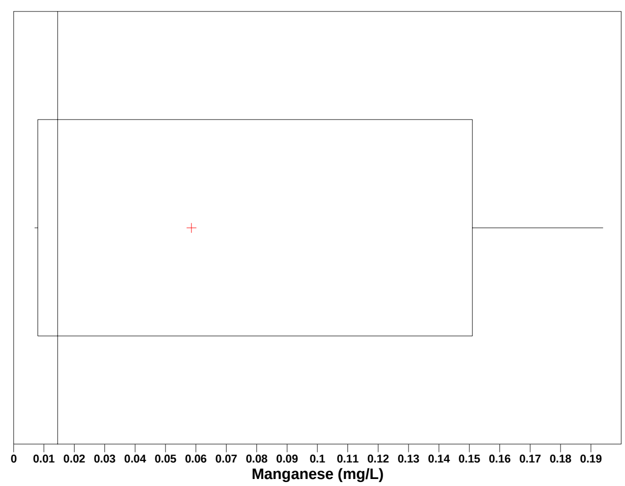
Data Plots for Manganese
Graphical displays of the data are shown below.

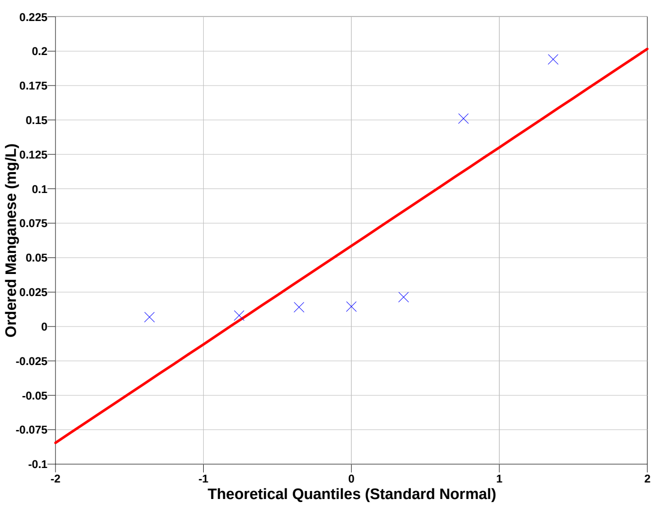
The Histogram is a plot of the fraction of the n observed data that fall within specified data “bins.” A histogram is generated by dividing the x axis (range of the observed data values) into "bins" and displaying the number of data in each bin as the height of a bar for the bin. The area of the bar is the fraction of the n data values that lie within the bin. The sum of the fractions for all bins equals one. A histogram is used to assess how the n data are distributed (spread) over their range of values. If the histogram is more or less symmetric and bell shaped, then the data may be normally distributed.

The Box and Whiskers plot is composed of a central box divided by a line, and with two lines extending out from the box, called the "whiskers". The line through the box is drawn at the median of the n data observed. The two ends of the box represent the 25th and 75th percentiles of the n data values, which are also called the lower and upper quartiles, respectively, of the data set. The sample mean (mean of the n data) is shown as a "+" sign. The upper whisker extends to the largest data value that is less than the upper quartile plus 1.5 times the interquartile range (upper quartile minus the lower quartile). The lower whisker extends to the smallest data value that is greater than the lower quartile minus 1.5 times the interquartile range. Extreme data values (greater or smaller than the ends of the whiskers) are plotted individually as blue Xs. A Box and Whiskers plot is used to assess the symmetry of the distribution of the data set. If the distribution is symmetrical, the box is divided into two equal halves by the median, the whiskers will be the same length, and the number of extreme data points will be distributed equally on either end of the plot.

The Q-Q plot graphs the quantiles of a set of n data against the quantiles of a specific distribution. We show here only the Q-Q plot for an assumed normal distribution. The pth quantile of a distribution of data is the data value, x_p, for which a fraction p of the distribution is less than x_p. If the data plotted on the normal distribution Q-Q plot closely follow a straight line, even at the ends of the line, then the data may be assumed to be normally distributed. If the data points deviate substantially from a linear line, then the data are not normally distributed.







□□□□□For more information on these plots consult Guidance for Data Quality Assessment, EPA QA/G-9, pgs 2.3-1 through 2.3-12. (http://www.epa.gov/quality/qa-docs.html).

Tests for Manganese

A goodness-of-fit test was performed to test whether the data set had been drawn from an underlying normal distribution. The Shapiro-Wilk (SW) test was used to test the null hypothesis that the data are normally distributed. The test was conducted at the 5% significance level, i.e., the probability the test incorrectly rejects the null hypothesis was set at 0.05.

NORMAL DISTRIBUTION TEST

Shapiro-Wilk Test Statistic	0.6927
Shapiro-Wilk 5% Critical Value	0.803

The calculated SW test statistic is less than the 5% Shapiro-Wilk critical value, so we can reject the hypothesis that the data are normal, or in other words the data do not appear to follow a normal distribution at the 5% level of significance. The Q-Q plot displayed above should be used to further assess the normality of the data.

Upper Confidence Limit on the True Mean
Two methods were used to compute the upper confidence limit (UCL) on the mean. The first is a parametric method that assumes a normal distribution. The second is the Chebyshev method, which requires no distributional assumption.

UCLs ON THE MEAN	
95% Parametric UCL	0.11655
95% Non-Parametric (Chebyshev) UCL	0.18865

Because the data do not appear to be normally distributed according to the goodness-of-fit test performed above, the non-parametric UCL (0.1887) may be a more accurate upper confidence limit on the true mean.

One-Sample t-Test
A one-sample t-test was performed to compare the sample mean to the action level. The null hypothesis used is that the true mean equals or exceeds the action level (AL). The t-test was conducted at the 5% significance level. The sample value *t* was computed using the following equation:

$$t = \frac{\bar{x} - AL}{SE}$$

where
x is the sample mean of the n=7 data,
AL is the action level or threshold (0.05),
SE is the standard error = (standard deviation) / (square root of n).

This *t* was then compared with the critical value $t_{0.95}$, where $t_{0.95}$ is the value of the t distribution with n-1=6 degrees of freedom for which the proportion of the distribution to the left of $t_{0.95}$ is 0.95. The null hypothesis will be rejected if $t < -t_{0.95}$.

ONE-SAMPLE t-TEST		
t-statistic	**Critical Value $t_{0.95}$**	**Null Hypothesis**
0.2862	1.9432	Cannot Reject

The test did not reject the null hypothesis that the mean value at the site exceeds the threshold, therefore conclude the true mean exceeds the threshold.

Because the data do not appear to be normally distributed, the MARSSIM Sign Test might be preferred over the One Sample t-Test. The following table represents the results of the MARSSIM Sign Test using the current data:

MARSSIM Sign Test		
Test Statistic (S+)	**95% Critical Value**	**Null Hypothesis**
5	6	Cannot Reject
Note: There may not be enough data to reject the null hypothesis (and conclude site is clean) with 95% confidence using the MARSSIM sign test.		

Appendix B

VSP Reports of Calculated Minimum Sample Quantity

Report 11

Area of Concern – 3

Minimum Sample Quantity Calculation for Surface Water using Ecological Benchmarks

Systematic sampling locations for comparing a mean with a fixed threshold (parametric)

Summary
This report summarizes the sampling design, associated statistical assumptions, as well as general guidelines for conducting post-sampling data analysis. Sampling plan components presented here include how many sampling locations to choose and where within the sampling area to collect those samples. The type of medium to sample (i.e., soil, groundwater, etc.) and how to analyze the samples (in-situ, fixed laboratory, etc.) are addressed in other sections of the sampling plan.

The following table summarizes the sampling design. A figure that shows sampling locations in the field and a table that lists sampling location coordinates are also provided below.

SUMMARY OF SAMPLING DESIGN	
Primary Objective of Design	Compare a site mean to a fixed threshold
Type of Sampling Design	Parametric
Sample Placement (Location) in the Field	Systematic with a random start location
Working (Null) Hypothesis	The mean value at the site exceeds the threshold
Formula for calculating number of sampling locations	Student's t-test
Calculated total number of samples	20
Number of samples on map [a]	20
Number of selected sample areas [b]	1
Specified sampling area [c]	1874440.39 ft^2
Size of grid / Area of grid cell [d]	328.969 feet / 93722 ft^2
Grid pattern	Triangular
Total cost of sampling [e]	$11,000.00

[a] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.
[b] The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.
[c] The sampling area is the total surface area of the selected colored sample areas on the map of the site.
[d] Size of grid / Area of grid cell gives the linear and square dimensions of the grid used to systematically place samples.
[e] Including measurement analyses and fixed overhead costs. See the Cost of Sampling section for an explanation of the costs presented here.

Area: AOC-3 IW					
X Coord	Y Coord	Label	Value	Type	Historical
1411554.0554	17202139.1475			Systematic	
1411718.5401	17202424.0434			Systematic	
1412376.4789	17202424.0434			Systematic	
1411883.0248	17202708.9392			Systematic	
1412211.9942	17202708.9392			Systematic	
1412540.9636	17202708.9392			Systematic	
1412211.9942	17203278.7309			Systematic	
1412376.4789	17203563.6268			Systematic	
1412540.9636	17203848.5227			Systematic	
1412869.9330	17203848.5227			Systematic	
1412705.4483	17204133.4185			Systematic	
1413034.4177	17204133.4185			Systematic	
1413692.3565	17204133.4185			Systematic	
1414185.8106	17204418.3144			Systematic	
1413034.4177	17204703.2102			Systematic	
1414021.3259	17204703.2102			Systematic	
1414350.2953	17204703.2102			Systematic	
1413198.9024	17204988.1061			Systematic	
1413856.8412	17204988.1061			Systematic	
1412705.4483	17205273.0019			Systematic	

Primary Sampling Objective

The primary purpose of sampling at this site is to compare a mean value of a site with a fixed threshold. The working hypothesis (or 'null' hypothesis) is that the mean value at the site is equal to or exceeds the threshold. The alternative hypothesis is that the mean value is less than the threshold. VSP calculates the number of samples required to reject the null hypothesis in favor of the alternative hypothesis, given a selected sampling approach and inputs to the associated equation.

Selected Sampling Approach
A parametric systematic sampling approach with a random start was used to determine the number of samples and to specify sampling locations. A parametric formula was chosen because the conceptual model and historical information (e.g., historical data from this site or a very similar site) indicate that parametric assumptions are reasonable. These assumptions will be examined in post-sampling data analysis.

Both parametric and non-parametric approaches rely on assumptions about the population. However, non-parametric approaches typically require fewer assumptions and allow for more uncertainty about the statistical distribution of values at the site. The trade-off is that if the parametric assumptions are valid, the required number of samples is usually less than the number of samples required by non-parametric approaches.

Locating the sample points over a systematic grid with a random start ensures spatial coverage of the site. Statistical analyses of systematically collected data are valid if a random start to the grid is used. One disadvantage of systematically collected samples is that spatial variability or patterns may not be discovered if the grid spacing is large relative to the spatial patterns.

Number of Total Samples: Calculation Equation and Inputs
The equation used to calculate the number of samples is based on a Student's t-test. For this site, the null hypothesis is rejected in favor of the alternative hypothesis if the sample mean is sufficiently smaller than the threshold. The number of samples to collect is calculated so that 1) there will be a high probability (1-β) of rejecting the null hypothesis if the alternative hypothesis is true and 2) a low probability (α) of rejecting the null hypothesis if the null hypothesis is true.

The formula used to calculate the number of samples is:

$$n = \frac{S^2}{\Delta^2}\left(Z_{1-\alpha} + Z_{1-\beta}\right)^2 + 0.5Z_{1-\alpha}^2$$

where
n is the number of samples,
S is the estimated standard deviation of the measured values including analytical error,
Δ is the width of the gray region,
α is the acceptable probability of incorrectly concluding the site mean is less than the threshold,
β is the acceptable probability of incorrectly concluding the site mean exceeds the threshold,
$Z_{1-\alpha}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\alpha}$ is 1-α,
$Z_{1-\beta}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\beta}$ is 1-β.

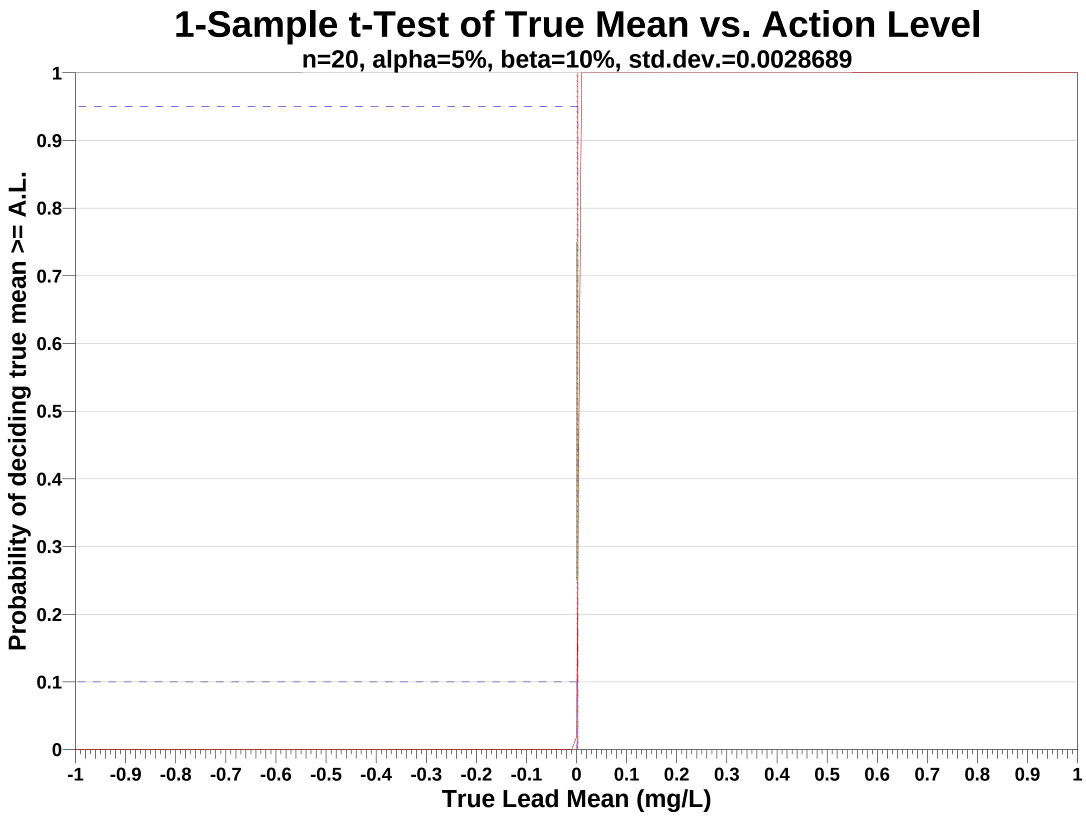
The values of these inputs that result in the calculated number of sampling locations are:

Analyte	n	Parameter					
		S	Δ	α	β	$Z_{1-\alpha}$ [a]	$Z_{1-\beta}$ [b]
Lead	20	0.0028689 mg/L	0.00196429 mg/L	0.05	0.1	1.64485	1.28155

[a] This value is automatically calculated by VSP based upon the user defined value of α.
[b] This value is automatically calculated by VSP based upon the user defined value of β.

The following figure is a performance goal diagram, described in EPA's QA/G-4 guidance (EPA, 2000). It shows the probability of concluding the sample area is dirty on the vertical axis versus a range of possible true mean values for the site on the horizontal axis. This graph contains all of the inputs to the number of samples equation and pictorially represents the calculation.

The red vertical line is shown at the threshold (action limit) on the horizontal axis. The width of the gray shaded area is equal to Δ; the upper horizontal dashed blue line is positioned at 1-α on the vertical axis; the lower horizontal dashed blue line is positioned at β on the vertical axis. The vertical green line is positioned at one standard deviation below the threshold. The shape of the red curve corresponds to the estimates of variability. The calculated number of samples results in the curve that passes through the lower bound of Δ at β and the upper bound of Δ at 1-α. If any of the inputs change, the number of samples that result in the correct curve changes.



Statistical Assumptions
The assumptions associated with the formulas for computing the number of samples are:

1. the sample mean is normally distributed (this happens if the data are roughly symmetric or the sample size is more than 30; for extremely skewed data sets, additional samples may be required for the sample mean to be normally distributed),
2. the variance estimate, S^2, is reasonable and representative of the population being sampled,
3. the population values are not spatially or temporally correlated, and
4. the sampling locations will be selected probabilistically.

The first three assumptions will be assessed in a post data collection analysis. The last assumption is valid because the gridded sample locations were selected based on a random start.

Sensitivity Analysis
The sensitivity of the calculation of number of samples was explored by varying the standard deviation, lower bound of gray region (% of action level), beta (%), probability of mistakenly concluding that μ > action level and alpha (%), probability of mistakenly concluding that μ < action level. The following table shows the results of this analysis.

Number of Samples							
AL=0.0025		**α=5**		**α=10**		**α=15**	
		s=0.0057378	**s=0.0028689**	**s=0.0057378**	**s=0.0028689**	**s=0.0057378**	**s=0.0028689**
LBGR=90	**β=5**	5703	1427	4512	1129	3788	948
	β=10	4513	1130	3462	866	2831	709
	β=15	3789	949	2832	709	2264	567
LBGR=80	**β=5**	1427	358	1129	283	948	238
	β=10	1130	284	866	218	709	178

	β=15	949	239	709	178	567	142
LBGR=70	**β=5**	635	160	503	127	422	106
	β=10	503	127	386	97	316	80
	β=15	423	107	316	80	253	64

s = Standard Deviation
LBGR = Lower Bound of Gray Region (% of Action Level)
β = Beta (%), Probability of mistakenly concluding that μ > action level
α = Alpha (%), Probability of mistakenly concluding that μ < action level
AL = Action Level (Threshold)

Cost of Sampling
The total cost of the completed sampling program depends on several cost inputs, some of which are fixed, and others that are based on the number of samples collected and measured. Based on the numbers of samples determined above, the estimated total cost of sampling and analysis at this site is $11,000.00, which averages out to a per sample cost of $550.00. The following table summarizes the inputs and resulting cost estimates.

COST INFORMATION			
Cost Details	**Per Analysis**	**Per Sample**	**20 Samples**
Field collection costs		$100.00	$2,000.00
Analytical costs	$400.00	$400.00	$8,000.00
Sum of Field & Analytical costs		**$500.00**	**$10,000.00**
Fixed planning and validation costs			$1,000.00
Total cost			**$11,000.00**

Data Analysis for Lead
The following data points were entered by the user for analysis.

Lead (mg/L)										
Rank	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0	0.0014	0.00235	0.0032	0.004	0.0048	0.0053	0.0102			

SUMMARY STATISTICS for Lead	
n	7
Min	0.0014
Max	0.0102
Range	0.0088
Mean	0.0044643
Median	0.004
Variance	8.2306e-006
StdDev	0.0028689
Std Error	0.0010843
Skewness	1.4721
Interquartile Range	0.00295
Percentiles	

1%	5%	10%	25%	50%	75%	90%	95%	99%
0.0014	0.0014	0.0014	0.00235	0.004	0.0053	0.0102	0.0102	0.0102

Outlier Test
Dixon's extreme value test was performed to test whether the lowest value is a statistical outlier. The test was conducted at the 5% significance level.

Data should not be excluded from analysis solely on the basis of the results of this or any other statistical test. If any values are flagged as possible outliers, further investigation is recommended to determine whether there is a plausible explanation that justifies removing or replacing them.

DIXON'S OUTLIER TEST for Lead	
Dixon Test Statistic	0.10795
Dixon 5% Critical Value	0.507

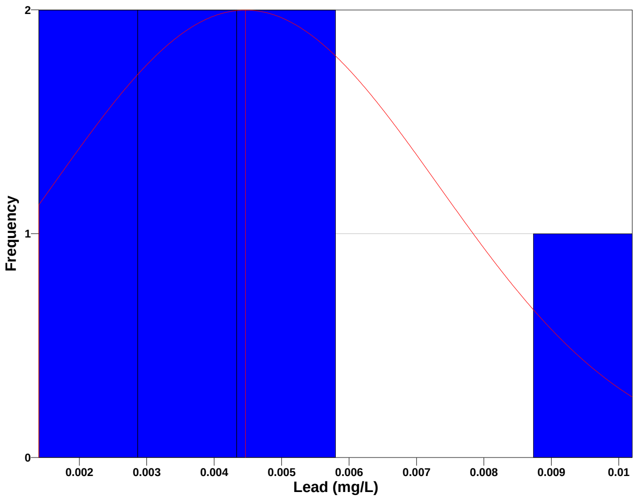
The calculated test statistic does not exceed the critical value, so the test cannot reject the null hypothesis that there are no outliers in the data, and concludes that the minimum value 0.0014 is not an outlier at the 5% significance level.

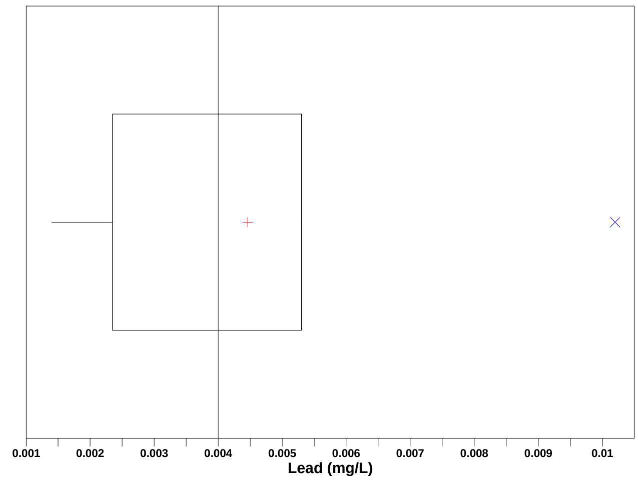
Data Plots for Lead
Graphical displays of the data are shown below.

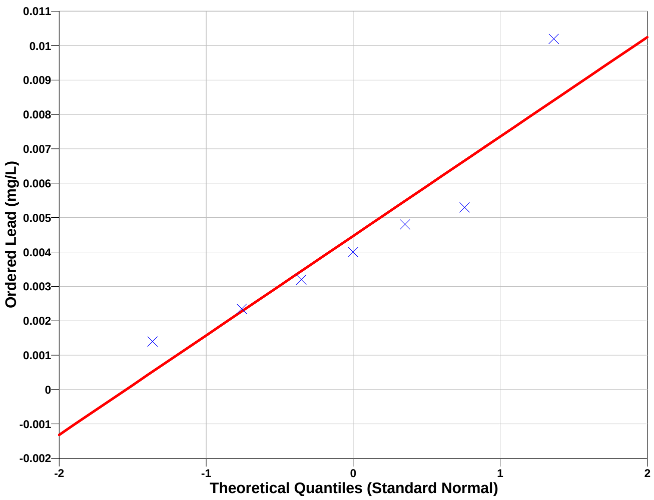
The Histogram is a plot of the fraction of the n observed data that fall within specified data “bins.” A histogram is generated by dividing the x axis (range of the observed data values) into "bins" and displaying the number of data in each bin as the height of a bar for the bin. The area of the bar is the fraction of the n data values that lie within the bin. The sum of the fractions for all bins equals one. A histogram is used to assess how the n data are distributed (spread) over their range of values. If the histogram is more or less symmetric and bell shaped, then the data may be normally distributed.

The Box and Whiskers plot is composed of a central box divided by a line, and with two lines extending out from the box, called the "whiskers". The line through the box is drawn at the median of the n data observed. The two ends of the box represent the 25th and 75th percentiles of the n data values, which are also called the lower and upper quartiles, respectively, of the data set. The sample mean (mean of the n data) is shown as a "+" sign. The upper whisker extends to the largest data value that is less than the upper quartile plus 1.5 times the interquartile range (upper quartile minus the lower quartile). The lower whisker extends to the smallest data value that is greater than the lower quartile minus 1.5 times the interquartile range. Extreme data values (greater or smaller than the ends of the whiskers) are plotted individually as blue Xs. A Box and Whiskers plot is used to assess the symmetry of the distribution of the data set. If the distribution is symmetrical, the box is divided into two equal halves by the median, the whiskers will be the same length, and the number of extreme data points will be distributed equally on either end of the plot.

The Q-Q plot graphs the quantiles of a set of n data against the quantiles of a specific distribution. We show here only the Q-Q plot for an assumed normal distribution. The pth quantile of a distribution of data is the data value, x_p, for which a fraction p of the distribution is less than x_p. If the data plotted on the normal distribution Q-Q plot closely follow a straight line, even at the ends of the line, then the data may be assumed to be normally distributed. If the data points deviate substantially from a linear line, then the data are not normally distributed.







□□□□□For more information on these plots consult Guidance for Data Quality Assessment, EPA QA/G-9, pgs 2.3-1 through 2.3-12. (http://www.epa.gov/quality/qa-docs.html).

Tests for Lead
A goodness-of-fit test was performed to test whether the data set had been drawn from an underlying normal distribution. The Shapiro-Wilk (SW) test was used to test the null hypothesis that the data are normally distributed. The test was conducted at the 5% significance level, i.e., the probability the test incorrectly rejects the null hypothesis was set at 0.05.

NORMAL DISTRIBUTION TEST	
Shapiro-Wilk Test Statistic	0.883
Shapiro-Wilk 5% Critical Value	0.803

The calculated SW test statistic exceeds the 5% Shapiro-Wilk critical value, so we cannot reject the hypothesis that the data are normal, or in other words the data appear to follow a normal distribution at the 5% level of significance. The Q-Q plot displayed above should be used to further assess the normality of the data.

Upper Confidence Limit on the True Mean
Two methods were used to compute the upper confidence limit (UCL) on the mean. The first is a parametric method that assumes a normal distribution. The second is the Chebyshev method, which requires no distributional assumption.

UCLs ON THE MEAN	
95% Parametric UCL	0.0065714

95% Non-Parametric (Chebyshev) UCL	0.0091908

Because the data appear to be normally distributed according to the goodness-of-fit test performed above, the parametric UCL (0.006571) may be a more accurate upper confidence limit on the true mean.

One-Sample t-Test

A one-sample t-test was performed to compare the sample mean to the action level. The null hypothesis used is that the true mean equals or exceeds the action level (AL). The t-test was conducted at the 5% significance level. The sample value *t* was computed using the following equation:

$$t = \frac{\bar{x} - AL}{SE}$$

where

x is the sample mean of the n=7 data,
AL is the action level or threshold (0.0025),
SE is the standard error = (standard deviation) / (square root of n).

This *t* was then compared with the critical value $t_{0.95}$, where $t_{0.95}$ is the value of the t distribution with n-1=6 degrees of freedom for which the proportion of the distribution to the left of $t_{0.95}$ is 0.95. The null hypothesis will be rejected if $t < -t_{0.95}$.

ONE-SAMPLE t-TEST		
t-statistic	**Critical Value $t_{0.95}$**	**Null Hypothesis**
1.8115	1.9432	Cannot Reject

The test did not reject the null hypothesis that the mean value at the site exceeds the threshold, therefore conclude the true mean exceeds the threshold.

Appendix B

VSP Reports of Calculated Minimum Sample Quantity

Report 12

Area of Concern – 3

Minimum Sample Quantity Calculation for Sediment using Human Health Benchmarks

Systematic sampling locations for comparing a mean with a fixed threshold (parametric)

Summary

This report summarizes the sampling design, associated statistical assumptions, as well as general guidelines for conducting post-sampling data analysis. Sampling plan components presented here include how many sampling locations to choose and where within the sampling area to collect those samples. The type of medium to sample (i.e., soil, groundwater, etc.) and how to analyze the samples (in-situ, fixed laboratory, etc.) are addressed in other sections of the sampling plan.

The following table summarizes the sampling design. A figure that shows sampling locations in the field and a table that lists sampling location coordinates are also provided below.

SUMMARY OF SAMPLING DESIGN	
Primary Objective of Design	Compare a site mean to a fixed threshold
Type of Sampling Design	Parametric
Sample Placement (Location) in the Field	Systematic with a random start location
Working (Null) Hypothesis	The mean value at the site exceeds the threshold
Formula for calculating number of sampling locations	Student's t-test
Calculated total number of samples	19
Number of samples on map [a]	19
Number of selected sample areas [b]	1
Specified sampling area [c]	1874440.39 ft^2
Size of grid / Area of grid cell [d]	337.515 feet / 98654.8 ft^2
Grid pattern	Triangular
Total cost of sampling [e]	$10,500.00

[a] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.
[b] The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.
[c] The sampling area is the total surface area of the selected colored sample areas on the map of the site.
[d] Size of grid / Area of grid cell gives the linear and square dimensions of the grid used to systematically place samples.
[e] Including measurement analyses and fixed overhead costs. See the Cost of Sampling section for an explanation of the costs presented here.

Area: AOC-3 IW					
X Coord	Y Coord	Label	Value	Type	Historical
1411718.7049	17202072.4251			Systematic	
1411549.9472	17202364.7221			Systematic	
1411718.7049	17202657.0191			Systematic	
1412056.2204	17202657.0191			Systematic	
1412393.7359	17202657.0191			Systematic	
1412224.9781	17202949.3161			Systematic	
1412562.4936	17203533.9100			Systematic	
1412731.2513	17203826.2070			Systematic	
1413743.7978	17203826.2070			Systematic	
1412562.4936	17204118.5040			Systematic	
1412900.0091	17204118.5040			Systematic	
1413912.5555	17204118.5040			Systematic	
1413068.7668	17204410.8010			Systematic	
1414081.3133	17204410.8010			Systematic	
1413912.5555	17204703.0980			Systematic	
1413406.2823	17204995.3949			Systematic	
1413743.7978	17204995.3949			Systematic	
1412562.4936	17205287.6919			Systematic	
1412900.0091	17205287.6919			Systematic	

Primary Sampling Objective
The primary purpose of sampling at this site is to compare a mean value of a site with a fixed threshold. The working hypothesis (or 'null' hypothesis) is that the mean value at the site is equal to or exceeds the threshold. The alternative hypothesis is that the mean value is less than the threshold. VSP calculates the number of samples required to reject the

null hypothesis in favor of the alternative hypothesis, given a selected sampling approach and inputs to the associated equation.

Selected Sampling Approach
A parametric systematic sampling approach with a random start was used to determine the number of samples and to specify sampling locations. A parametric formula was chosen because the conceptual model and historical information (e.g., historical data from this site or a very similar site) indicate that parametric assumptions are reasonable. These assumptions will be examined in post-sampling data analysis.

Both parametric and non-parametric approaches rely on assumptions about the population. However, non-parametric approaches typically require fewer assumptions and allow for more uncertainty about the statistical distribution of values at the site. The trade-off is that if the parametric assumptions are valid, the required number of samples is usually less than the number of samples required by non-parametric approaches.

Locating the sample points over a systematic grid with a random start ensures spatial coverage of the site. Statistical analyses of systematically collected data are valid if a random start to the grid is used. One disadvantage of systematically collected samples is that spatial variability or patterns may not be discovered if the grid spacing is large relative to the spatial patterns.

Number of Total Samples: Calculation Equation and Inputs
The equation used to calculate the number of samples is based on a Student's t-test. For this site, the null hypothesis is rejected in favor of the alternative hypothesis if the sample mean is sufficiently smaller than the threshold. The number of samples to collect is calculated so that 1) there will be a high probability ($1-\beta$) of rejecting the null hypothesis if the alternative hypothesis is true and 2) a low probability (α) of rejecting the null hypothesis if the null hypothesis is true.

The formula used to calculate the number of samples is:

$$n = \frac{S^2}{\Delta^2}\left(Z_{1-\alpha} + Z_{1-\beta}\right)^2 + 0.5Z_{1-\alpha}^2$$

where
n is the number of samples,
S is the estimated standard deviation of the measured values including analytical error,
Δ is the width of the gray region,
α is the acceptable probability of incorrectly concluding the site mean is less than the threshold,
β is the acceptable probability of incorrectly concluding the site mean exceeds the threshold,
$Z_{1-\alpha}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\alpha}$ is $1-\alpha$,
$Z_{1-\beta}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\beta}$ is $1-\beta$.

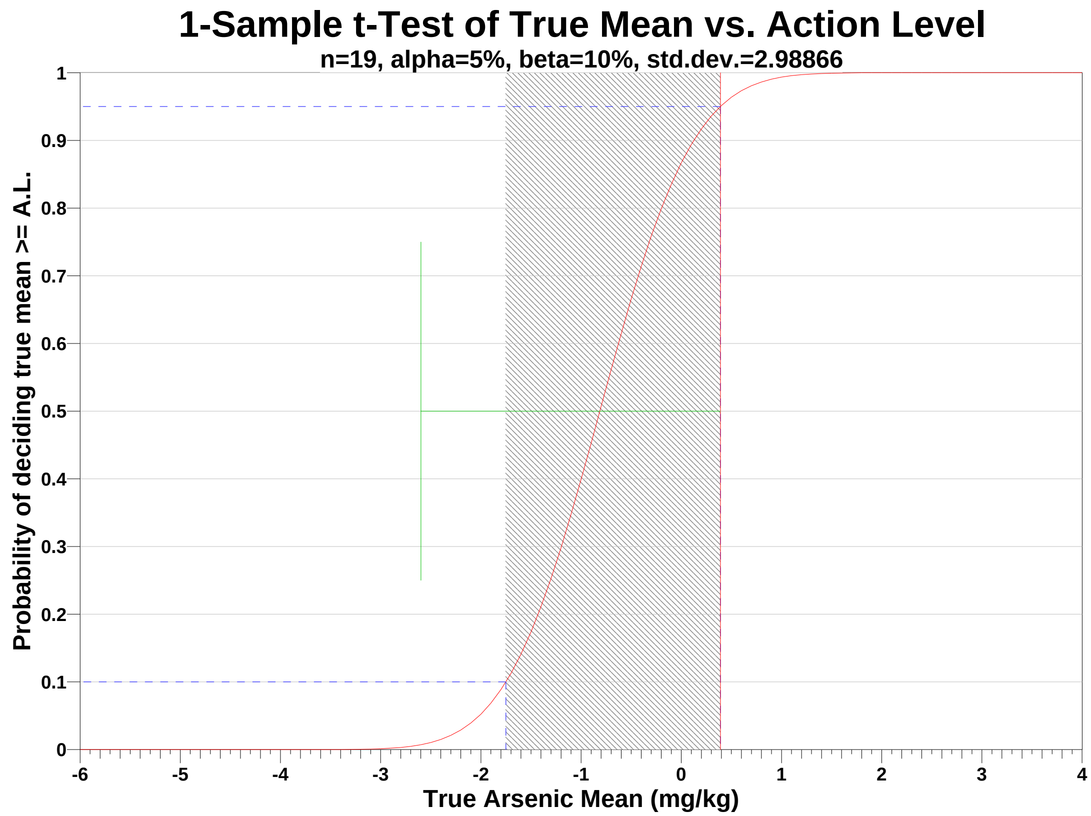
The values of these inputs that result in the calculated number of sampling locations are:

Analyte	n	Parameter					
		S	Δ	α	β	$Z_{1-\alpha}$ [a]	$Z_{1-\beta}$ [b]
Arsenic	19	2.98866 mg/kg	2.14068 mg/kg	0.05	0.1	1.64485	1.28155

[a] This value is automatically calculated by VSP based upon the user defined value of α.
[b] This value is automatically calculated by VSP based upon the user defined value of β.

The following figure is a performance goal diagram, described in EPA's QA/G-4 guidance (EPA, 2000). It shows the probability of concluding the sample area is dirty on the vertical axis versus a range of possible true mean values for the site on the horizontal axis. This graph contains all of the inputs to the number of samples equation and pictorially represents the calculation.

The red vertical line is shown at the threshold (action limit) on the horizontal axis. The width of the gray shaded area is equal to Δ; the upper horizontal dashed blue line is positioned at $1-\alpha$ on the vertical axis; the lower horizontal dashed blue line is positioned at β on the vertical axis. The vertical green line is positioned at one standard deviation below the threshold. The shape of the red curve corresponds to the estimates of variability. The calculated number of samples results in the curve that passes through the lower bound of Δ at β and the upper bound of Δ at $1-\alpha$. If any of the inputs change, the number of samples that result in the correct curve changes.



Statistical Assumptions

The assumptions associated with the formulas for computing the number of samples are:

1. the sample mean is normally distributed (this happens if the data are roughly symmetric or the sample size is more than 30; for extremely skewed data sets, additional samples may be required for the sample mean to be normally distributed),
2. the variance estimate, S^2, is reasonable and representative of the population being sampled,
3. the population values are not spatially or temporally correlated, and
4. the sampling locations will be selected probabilistically.

The first three assumptions will be assessed in a post data collection analysis. The last assumption is valid because the gridded sample locations were selected based on a random start.

Sensitivity Analysis

The sensitivity of the calculation of number of samples was explored by varying the standard deviation, lower bound of gray region (% of action level), beta (%), probability of mistakenly concluding that μ > action level and alpha (%), probability of mistakenly concluding that μ < action level. The following table shows the results of this analysis.

Number of Samples							
AL=0.39		α=5		α=10		α=15	
		s=5.97732	s=2.98866	s=5.97732	s=2.98866	s=5.97732	s=2.98866
LBGR=90	β=5	254215	63555	201166	50293	168878	42220
	β=10	201167	50293	154319	38581	126214	31554
	β=15	168879	42221	126215	31555	100933	25234
LBGR=80	β=5	63555	15890	50293	12574	42220	10556
	β=10	50293	12575	38581	9646	31554	7889
	β=15	42221	10557	31555	7890	25234	6309

LBGR=70	**β=5**	28248	7063	22353	5589	18765	4692
	β=10	22354	5590	17148	4288	14025	3507
	β=15	18766	4693	14025	3507	11216	2805

s = Standard Deviation
LBGR = Lower Bound of Gray Region (% of Action Level)
β = Beta (%), Probability of mistakenly concluding that μ > action level
α = Alpha (%), Probability of mistakenly concluding that μ < action level
AL = Action Level (Threshold)

Cost of Sampling
The total cost of the completed sampling program depends on several cost inputs, some of which are fixed, and others that are based on the number of samples collected and measured. Based on the numbers of samples determined above, the estimated total cost of sampling and analysis at this site is $10,500.00, which averages out to a per sample cost of $552.63. The following table summarizes the inputs and resulting cost estimates.

COST INFORMATION			
Cost Details	**Per Analysis**	**Per Sample**	**19 Samples**
Field collection costs		$100.00	$1,900.00
Analytical costs	$400.00	$400.00	$7,600.00
Sum of Field & Analytical costs		**$500.00**	**$9,500.00**
Fixed planning and validation costs			$1,000.00
Total cost			**$10,500.00**

Data Analysis for Arsenic
The following data points were entered by the user for analysis.

Arsenic (mg/kg)										
Rank	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0	0.31	0.33	0.43	0.45	0.455	0.625	0.67	0.74	0.75	0.75
10	0.79	0.86	0.86	1.1	1.3	1.3	1.4	1.4	1.4	1.5
20	1.5	1.5	1.6	1.6	1.6	1.7	1.7	2.13	2.2	2.3
30	2.4	2.4	2.6	2.8	2.8	3.3	4.7	4.8	5	6.3
40	6.3	6.5	8.9	17.3						

SUMMARY STATISTICS for Arsenic	
n	44
Min	0.31
Max	17.3
Range	16.99
Mean	2.5307
Median	1.55
Variance	8.9321
StdDev	2.9887
Std Error	0.45056

Skewness	3.2631							
Interquartile Range	1.9425							
Percentiles								
1%	**5%**	**10%**	**25%**	**50%**	**75%**	**90%**	**95%**	**99%**
0.31	0.355	0.4525	0.8075	1.55	2.75	6.3	8.3	17.3

Outlier Test
Rosner's test for multiple outliers was performed to test whether the most extreme value is a statistical outlier. The test was conducted at the 5% significance level.

Data should not be excluded from analysis solely on the basis of the results of this or any other statistical test. If any values are flagged as possible outliers, further investigation is recommended to determine whether there is a plausible explanation that justifies removing or replacing them.

In using Rosner's test to detect up to 1 outlier, a test statistic R_1 is calculated, and compared with a critical value C_1 to test the hypothesis that there is one outlier in the data.

ROSNER'S OUTLIER TEST for Arsenic			
k	**Test Statistic R_k**	**5% Critical Value C_k**	**Significant?**
1	4.942	3.08	Yes

The test statistic 4.942 exceeded the corresponding critical value, therefore that test is significant and we conclude that the most extreme value is an outlier at the 5% significance level.

SUSPECTED OUTLIERS for Arsenic	
1	17.3

A normal distribution test indicated that the data do not appear to be normally distributed, so further investigation is recommended before using the results of this test. Because Rosner's test can be used only when the data without the suspected outlier are approximately normally distributed, a Shapiro-Wilk test for normality was performed at a 5% significance level.

NORMAL DISTRIBUTION TEST (excluding outliers)	
Shapiro-Wilk Test Statistic	0.794
Shapiro-Wilk 5% Critical Value	0.943

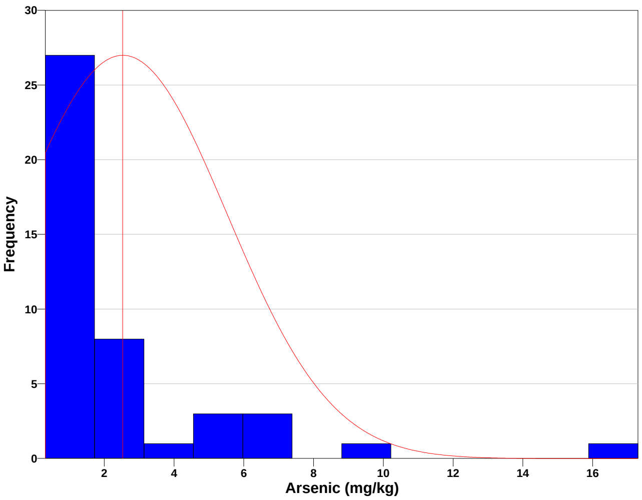
The calculated Shapiro-Wilk test statistic is less than the 5% Shapiro-Wilk critical value, so the test rejects the hypothesis that the data are normal and concludes that the data, excluding the most extreme value, do not appear to follow a normal distribution at the 5% level of significance. Rosner's test may not be appropriate if the assumption of normally distributed data is not justified for this data set. Examine the Q-Q plot displayed below to further assess the normality of the data.

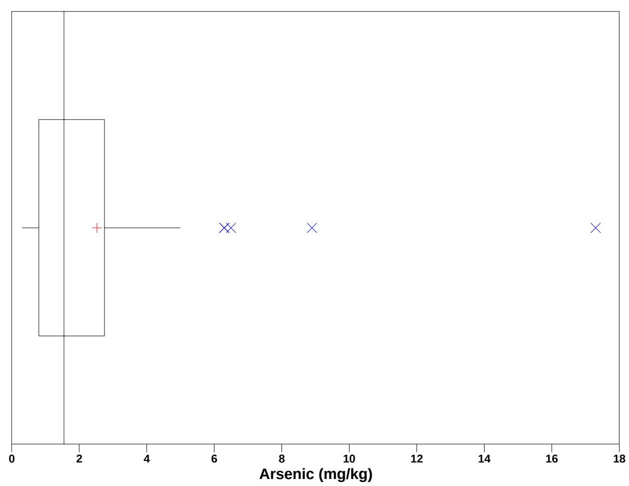
Data Plots for Arsenic
Graphical displays of the data are shown below.

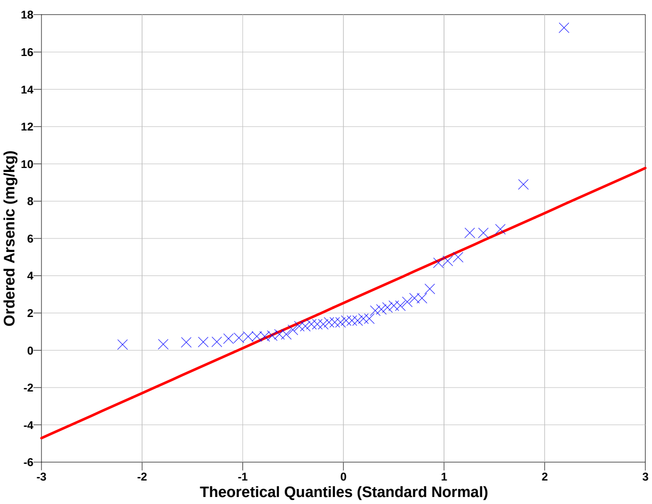
The Histogram is a plot of the fraction of the n observed data that fall within specified data “bins.” A histogram is generated by dividing the x axis (range of the observed data values) into "bins" and displaying the number of data in each bin as the height of a bar for the bin. The area of the bar is the fraction of the n data values that lie within the bin. The sum of the fractions for all bins equals one. A histogram is used to assess how the n data are distributed (spread) over their range of values. If the histogram is more or less symmetric and bell shaped, then the data may be normally distributed.

The Box and Whiskers plot is composed of a central box divided by a line, and with two lines extending out from the box, called the "whiskers". The line through the box is drawn at the median of the n data observed. The two ends of the box represent the 25th and 75th percentiles of the n data values, which are also called the lower and upper quartiles, respectively, of the data set. The sample mean (mean of the n data) is shown as a "+" sign. The upper whisker extends to the largest data value that is less than the upper quartile plus 1.5 times the interquartile range (upper quartile minus the lower quartile). The lower whisker extends to the smallest data value that is greater than the lower quartile minus 1.5 times the interquartile range. Extreme data values (greater or smaller than the ends of the whiskers) are plotted individually as blue Xs. A Box and Whiskers plot is used to assess the symmetry of the distribution of the data set. If the distribution is symmetrical, the box is divided into two equal halves by the median, the whiskers will be the same length, and the number of extreme data points will be distributed equally on either end of the plot.

The Q-Q plot graphs the quantiles of a set of n data against the quantiles of a specific distribution. We show here only the Q-Q plot for an assumed normal distribution. The p^{th} quantile of a distribution of data is the data value, x_p, for which a fraction p of the distribution is less than x_p. If the data plotted on the normal distribution Q-Q plot closely follow a straight line, even at the ends of the line, then the data may be assumed to be normally distributed. If the data points deviate substantially from a linear line, then the data are not normally distributed.







For more information on these plots consult Guidance for Data Quality Assessment, EPA QA/G-9, pgs 2.3-1 through 2.3-12. (http://www.epa.gov/quality/qa-docs.html).

Tests for Arsenic

A goodness-of-fit test was performed to test whether the data set had been drawn from an underlying normal distribution. The Shapiro-Wilk (SW) test was used to test the null hypothesis that the data are normally distributed. The test was conducted at the 5% significance level, i.e., the probability the test incorrectly rejects the null hypothesis was set at 0.05.

NORMAL DISTRIBUTION TEST

Shapiro-Wilk Test Statistic	0.6543
Shapiro-Wilk 5% Critical Value	0.944

The calculated SW test statistic is less than the 5% Shapiro-Wilk critical value, so we can reject the hypothesis that the data are normal, or in other words the data do not appear to follow a normal distribution at the 5% level of significance. The Q-Q plot displayed above should be used to further assess the normality of the data.

Upper Confidence Limit on the True Mean
Two methods were used to compute the upper confidence limit (UCL) on the mean. The first is a parametric method that assumes a normal distribution. The second is the Chebyshev method, which requires no distributional assumption.

UCLs ON THE MEAN	
95% Parametric UCL	3.2881
95% Non-Parametric (Chebyshev) UCL	4.4946

Because the data do not appear to be normally distributed according to the goodness-of-fit test performed above, the non-parametric UCL (4.495) may be a more accurate upper confidence limit on the true mean.

One-Sample t-Test
A one-sample t-test was performed to compare the sample mean to the action level. The null hypothesis used is that the true mean equals or exceeds the action level (AL). The t-test was conducted at the 5% significance level. The sample value *t* was computed using the following equation:

$$t = \frac{\bar{x} - AL}{SE}$$

where
x is the sample mean of the n=44 data,
AL is the action level or threshold (0.39),
SE is the standard error = (standard deviation) / (square root of n).

This *t* was then compared with the critical value $t_{0.95}$, where $t_{0.95}$ is the value of the t distribution with n-1=43 degrees of freedom for which the proportion of the distribution to the left of $t_{0.95}$ is 0.95. The null hypothesis will be rejected if $t < -t_{0.95}$.

ONE-SAMPLE t-TEST		
t-statistic	**Critical Value $t_{0.95}$**	**Null Hypothesis**
4.7512	1.6811	Cannot Reject

The test did not reject the null hypothesis that the mean value at the site exceeds the threshold, therefore conclude the true mean exceeds the threshold.

Because the data do not appear to be normally distributed, the MARSSIM Sign Test might be preferred over the One Sample t-Test. The following table represents the results of the MARSSIM Sign Test using the current data:

MARSSIM Sign Test		
Test Statistic (S+)	**95% Critical Value**	**Null Hypothesis**
2	27	Cannot Reject
Note: There may not be enough data to reject the null hypothesis (and conclude site is clean) with 95% confidence using the MARSSIM sign test.		

Appendix B

VSP Reports of Calculated Minimum Sample Quantity

Report 13

Area of Concern – 3

Minimum Sample Quantity Calculation for Sediment using Ecological Benchmarks

Systematic sampling locations for comparing a mean with a fixed threshold (parametric)

Summary
This report summarizes the sampling design, associated statistical assumptions, as well as general guidelines for conducting post-sampling data analysis. Sampling plan components presented here include how many sampling locations to choose and where within the sampling area to collect those samples. The type of medium to sample (i.e., soil, groundwater, etc.) and how to analyze the samples (in-situ, fixed laboratory, etc.) are addressed in other sections of the sampling plan.

The following table summarizes the sampling design. A figure that shows sampling locations in the field and a table that lists sampling location coordinates are also provided below.

SUMMARY OF SAMPLING DESIGN	
Primary Objective of Design	Compare a site mean to a fixed threshold
Type of Sampling Design	Parametric
Sample Placement (Location) in the Field	Systematic with a random start location
Working (Null) Hypothesis	The mean value at the site exceeds the threshold
Formula for calculating number of sampling locations	Student's t-test
Calculated total number of samples	36
Number of samples on map [a]	36
Number of selected sample areas [b]	1
Specified sampling area [c]	1874440.39 ft^2
Size of grid / Area of grid cell [d]	245.199 feet / 52067.8 ft^2
Grid pattern	Triangular
Total cost of sampling [e]	$19,000.00

[a] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.
[b] The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.
[c] The sampling area is the total surface area of the selected colored sample areas on the map of the site.
[d] Size of grid / Area of grid cell gives the linear and square dimensions of the grid used to systematically place samples.
[e] Including measurement analyses and fixed overhead costs. See the Cost of Sampling section for an explanation of the costs presented here.

Area: AOC-3 IW					
X Coord	Y Coord	Label	Value	Type	Historical
1411697.4806	17201989.6023			Systematic	
1411574.8810	17202201.9512			Systematic	
1411820.0803	17202201.9512			Systematic	
1412310.4789	17202201.9512			Systematic	
1411697.4806	17202414.3000			Systematic	
1412433.0786	17202414.3000			Systematic	
1411820.0803	17202626.6488			Systematic	
1412065.2796	17202626.6488			Systematic	
1412310.4789	17202626.6488			Systematic	
1412555.6782	17202626.6488			Systematic	
1412187.8793	17202838.9977			Systematic	
1412433.0786	17202838.9977			Systematic	
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1412187.8793	17203263.6953			Systematic	
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1412555.6782	17203476.0442			Systematic	
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1412800.8775	17203900.7418			Systematic	
1413781.6748	17203900.7418			Systematic	
1412678.2779	17204113.0907			Systematic	
1412923.4772	17204113.0907			Systematic	

1413904.2745	17204113.0907			Systematic	
1412800.8775	17204325.4395			Systematic	
1413046.0769	17204325.4395			Systematic	
1414026.8741	17204325.4395			Systematic	
1413168.6765	17204537.7883			Systematic	
1414149.4738	17204537.7883			Systematic	
1414026.8741	17204750.1372			Systematic	
1413168.6765	17204962.4860			Systematic	
1413659.0751	17204962.4860			Systematic	
1412800.8775	17205174.8348			Systematic	
1413046.0769	17205174.8348			Systematic	
1413536.4755	17205174.8348			Systematic	
1412678.2779	17205387.1837			Systematic	
1412923.4772	17205387.1837			Systematic	

Primary Sampling Objective
The primary purpose of sampling at this site is to compare a mean value of a site with a fixed threshold. The working hypothesis (or 'null' hypothesis) is that the mean value at the site is equal to or exceeds the threshold. The alternative hypothesis is that the mean value is less than the threshold. VSP calculates the number of samples required to reject the null hypothesis in favor of the alternative hypothesis, given a selected sampling approach and inputs to the associated equation.

Selected Sampling Approach
A parametric systematic sampling approach with a random start was used to determine the number of samples and to specify sampling locations. A parametric formula was chosen because the conceptual model and historical information (e.g., historical data from this site or a very similar site) indicate that parametric assumptions are reasonable. These assumptions will be examined in post-sampling data analysis.

Both parametric and non-parametric approaches rely on assumptions about the population. However, non-parametric approaches typically require fewer assumptions and allow for more uncertainty about the statistical distribution of values at the site. The trade-off is that if the parametric assumptions are valid, the required number of samples is usually less than the number of samples required by non-parametric approaches.

Locating the sample points over a systematic grid with a random start ensures spatial coverage of the site. Statistical analyses of systematically collected data are valid if a random start to the grid is used. One disadvantage of systematically collected samples is that spatial variability or patterns may not be discovered if the grid spacing is large relative to the spatial patterns.

Number of Total Samples: Calculation Equation and Inputs
The equation used to calculate the number of samples is based on a Student's t-test. For this site, the null hypothesis is rejected in favor of the alternative hypothesis if the sample mean is sufficiently smaller than the threshold. The number of samples to collect is calculated so that 1) there will be a high probability ($1-\beta$) of rejecting the null hypothesis if the alternative hypothesis is true and 2) a low probability (α) of rejecting the null hypothesis if the null hypothesis is true.

The formula used to calculate the number of samples is:

$$n = \frac{S^2}{\Delta^2}\left(Z_{1-\alpha} + Z_{1-\beta}\right)^2 + 0.5Z_{1-\alpha}^2$$

where
n is the number of samples,
S is the estimated standard deviation of the measured values including analytical error,
Δ is the width of the gray region,

α is the acceptable probability of incorrectly concluding the site mean is less than the threshold,
β is the acceptable probability of incorrectly concluding the site mean exceeds the threshold,
$Z_{1-\alpha}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\alpha}$ is $1-\alpha$,
$Z_{1-\beta}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\beta}$ is $1-\beta$.

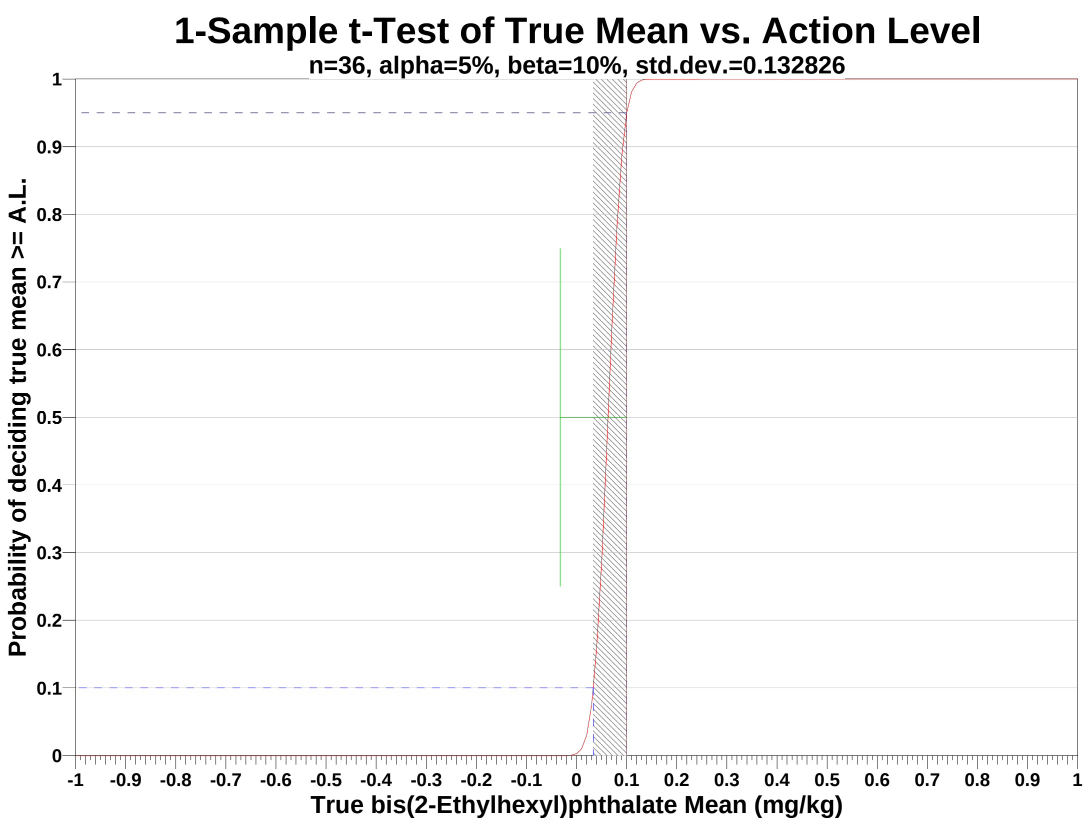
The values of these inputs that result in the calculated number of sampling locations are:

Analyte	n	Parameter					
		S	Δ	α	β	$Z_{1-\alpha}$ [a]	$Z_{1-\beta}$ [b]
bis(2-Ethylhexyl)phthalate	36	0.132826 mg/kg	0.066413 mg/kg	0.05	0.1	1.64485	1.28155

[a] This value is automatically calculated by VSP based upon the user defined value of α.
[b] This value is automatically calculated by VSP based upon the user defined value of β.

The following figure is a performance goal diagram, described in EPA's QA/G-4 guidance (EPA, 2000). It shows the probability of concluding the sample area is dirty on the vertical axis versus a range of possible true mean values for the site on the horizontal axis. This graph contains all of the inputs to the number of samples equation and pictorially represents the calculation.

The red vertical line is shown at the threshold (action limit) on the horizontal axis. The width of the gray shaded area is equal to Δ; the upper horizontal dashed blue line is positioned at $1-\alpha$ on the vertical axis; the lower horizontal dashed blue line is positioned at β on the vertical axis. The vertical green line is positioned at one standard deviation below the threshold. The shape of the red curve corresponds to the estimates of variability. The calculated number of samples results in the curve that passes through the lower bound of Δ at β and the upper bound of Δ at $1-\alpha$. If any of the inputs change, the number of samples that result in the correct curve changes.



Statistical Assumptions
The assumptions associated with the formulas for computing the number of samples are:
1. the sample mean is normally distributed (this happens if the data are roughly symmetric or the sample size is more than 30; for extremely skewed data sets, additional samples may be required for the sample mean to be normally

distributed),
2. the variance estimate, S^2, is reasonable and representative of the population being sampled,
3. the population values are not spatially or temporally correlated, and
4. the sampling locations will be selected probabilistically.

The first three assumptions will be assessed in a post data collection analysis. The last assumption is valid because the gridded sample locations were selected based on a random start.

Sensitivity Analysis
The sensitivity of the calculation of number of samples was explored by varying the standard deviation, lower bound of gray region (% of action level), beta (%), probability of mistakenly concluding that μ > action level and alpha (%), probability of mistakenly concluding that μ < action level. The following table shows the results of this analysis.

Number of Samples							
AL=0.1		**α=5**		**α=10**		**α=15**	
		s=0.265652	**s=0.132826**	**s=0.265652**	**s=0.132826**	**s=0.265652**	**s=0.132826**
LBGR=90	**β=5**	7639	1911	6045	1512	5075	1269
	β=10	6045	1513	4637	1160	3793	949
	β=15	5075	1270	3793	949	3033	759
LBGR=80	**β=5**	1911	479	1512	379	1269	318
	β=10	1513	380	1160	291	949	238
	β=15	1270	319	949	238	759	191
LBGR=70	**β=5**	850	214	673	169	565	142
	β=10	673	170	516	130	422	106
	β=15	566	143	423	107	338	85

s = Standard Deviation
LBGR = Lower Bound of Gray Region (% of Action Level)
β = Beta (%), Probability of mistakenly concluding that μ > action level
α = Alpha (%), Probability of mistakenly concluding that μ < action level
AL = Action Level (Threshold)

Cost of Sampling
The total cost of the completed sampling program depends on several cost inputs, some of which are fixed, and others that are based on the number of samples collected and measured. Based on the numbers of samples determined above, the estimated total cost of sampling and analysis at this site is $19,000.00, which averages out to a per sample cost of $527.78. The following table summarizes the inputs and resulting cost estimates.

COST INFORMATION			
Cost Details	**Per Analysis**	**Per Sample**	**36 Samples**
Field collection costs		$100.00	$3,600.00
Analytical costs	$400.00	$400.00	$14,400.00
Sum of Field & Analytical costs		**$500.00**	**$18,000.00**
Fixed planning and validation costs			$1,000.00
Total cost			**$19,000.00**

Data Analysis for bis(2-Ethylhexyl)phthalate
The following data points were entered by the user for analysis.

bis(2-Ethylhexyl)phthalate (mg/kg)

Rank	1	2	3	4	5	6	7	8	9	10
0	0.046	0.0465	0.047	0.0479	0.048	0.0483	0.0485	0.0485	0.0485	0.049
10	0.0495	0.0495	0.0498	0.05	0.05	0.05	0.05	0.0525	0.055	0.055
20	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.06	0.06	0.065
30	0.065	0.065	0.065	0.075	0.085	0.095	0.1	0.136	0.153	0.215
40	0.342	0.408	0.444	0.729						

SUMMARY STATISTICS for bis(2-Ethylhexyl)phthalate								
n	44							
Min	0.046							
Max	0.729							
Range	0.683							
Mean	0.1031							
Median	0.055							
Variance	0.017642							
StdDev	0.13282							
Std Error	0.020024							
Skewness	3.3692							
Interquartile Range	0.023							
Percentiles								
1%	**5%**	**10%**	**25%**	**50%**	**75%**	**90%**	**95%**	**99%**
0.046	0.04663	0.04795	0.0495	0.055	0.0725	0.2785	0.435	0.729

Outlier Test
Rosner's test for multiple outliers was performed to test whether the most extreme value is a statistical outlier. The test was conducted at the 5% significance level.

Data should not be excluded from analysis solely on the basis of the results of this or any other statistical test. If any values are flagged as possible outliers, further investigation is recommended to determine whether there is a plausible explanation that justifies removing or replacing them.

In using Rosner's test to detect up to 1 outlier, a test statistic R_1 is calculated, and compared with a critical value C_1 to test the hypothesis that there is one outlier in the data.

ROSNER'S OUTLIER TEST for bis(2-Ethylhexyl)phthalate			
k	**Test Statistic R_k**	**5% Critical Value C_k**	**Significant?**
1	4.712	3.08	Yes

The test statistic 4.712 exceeded the corresponding critical value, therefore that test is significant and we conclude that the most extreme value is an outlier at the 5% significance level.

SUSPECTED OUTLIERS for bis(2-Ethylhexyl)phthalate	
1	0.729

A normal distribution test indicated that the data do not appear to be normally distributed, so further investigation is recommended before using the results of this test. Because Rosner's test can be used only when the data without the suspected outlier are approximately normally distributed, a Shapiro-Wilk test for normality was performed at a 5% significance level.

NORMAL DISTRIBUTION TEST (excluding outliers)	
Shapiro-Wilk Test Statistic	0.4909
Shapiro-Wilk 5% Critical Value	0.943

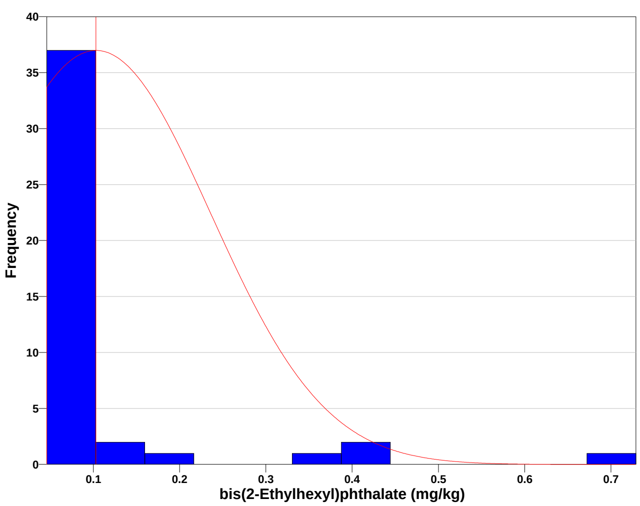
The calculated Shapiro-Wilk test statistic is less than the 5% Shapiro-Wilk critical value, so the test rejects the hypothesis that the data are normal and concludes that the data, excluding the most extreme value, do not appear to follow a normal distribution at the 5% level of significance. Rosner's test may not be appropriate if the assumption of normally distributed data is not justified for this data set. Examine the Q-Q plot displayed below to further assess the normality of the data.

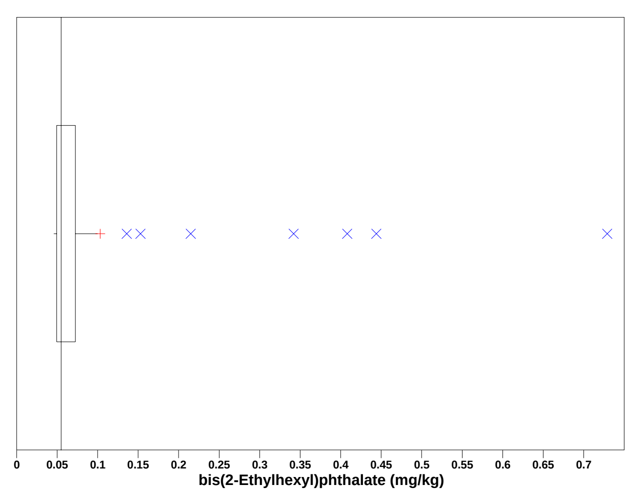
Data Plots for bis(2-Ethylhexyl)phthalate
Graphical displays of the data are shown below.

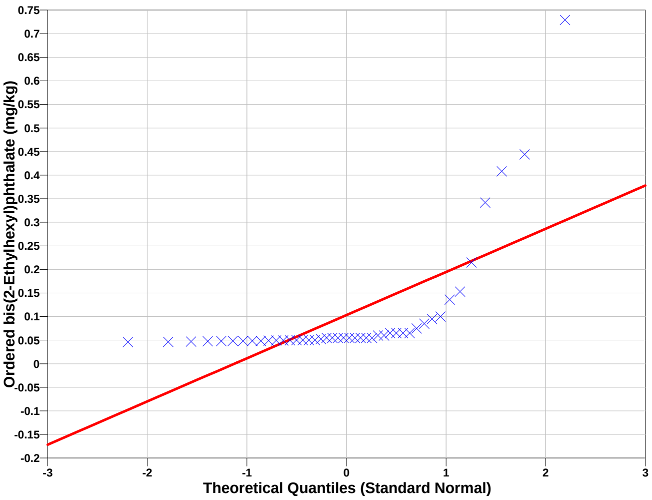
The Histogram is a plot of the fraction of the n observed data that fall within specified data "bins." A histogram is generated by dividing the x axis (range of the observed data values) into "bins" and displaying the number of data in each bin as the height of a bar for the bin. The area of the bar is the fraction of the n data values that lie within the bin. The sum of the fractions for all bins equals one. A histogram is used to assess how the n data are distributed (spread) over their range of values. If the histogram is more or less symmetric and bell shaped, then the data may be normally distributed.

The Box and Whiskers plot is composed of a central box divided by a line, and with two lines extending out from the box, called the "whiskers". The line through the box is drawn at the median of the n data observed. The two ends of the box represent the 25th and 75th percentiles of the n data values, which are also called the lower and upper quartiles, respectively, of the data set. The sample mean (mean of the n data) is shown as a "+" sign. The upper whisker extends to the largest data value that is less than the upper quartile plus 1.5 times the interquartile range (upper quartile minus the lower quartile). The lower whisker extends to the smallest data value that is greater than the lower quartile minus 1.5 times the interquartile range. Extreme data values (greater or smaller than the ends of the whiskers) are plotted individually as blue Xs. A Box and Whiskers plot is used to assess the symmetry of the distribution of the data set. If the distribution is symmetrical, the box is divided into two equal halves by the median, the whiskers will be the same length, and the number of extreme data points will be distributed equally on either end of the plot.

The Q-Q plot graphs the quantiles of a set of n data against the quantiles of a specific distribution. We show here only the Q-Q plot for an assumed normal distribution. The pth quantile of a distribution of data is the data value, x_p, for which a fraction p of the distribution is less than x_p. If the data plotted on the normal distribution Q-Q plot closely follow a straight line, even at the ends of the line, then the data may be assumed to be normally distributed. If the data points deviate substantially from a linear line, then the data are not normally distributed.







□□□□□For more information on these plots consult Guidance for Data Quality Assessment, EPA QA/G-9, pgs 2.3-1 through 2.3-12. (http://www.epa.gov/quality/qa-docs.html).

Tests for bis(2-Ethylhexyl)phthalate
A goodness-of-fit test was performed to test whether the data set had been drawn from an underlying normal distribution. The Shapiro-Wilk (SW) test was used to test the null hypothesis that the data are normally distributed. The test was conducted at the 5% significance level, i.e., the probability the test incorrectly rejects the null hypothesis was set at 0.05.

NORMAL DISTRIBUTION TEST	
Shapiro-Wilk Test Statistic	0.4804
Shapiro-Wilk 5% Critical Value	0.944

The calculated SW test statistic is less than the 5% Shapiro-Wilk critical value, so we can reject the hypothesis that the data are normal, or in other words the data do not appear to follow a normal distribution at the 5% level of significance. The Q-Q plot displayed above should be used to further assess the normality of the data.

Upper Confidence Limit on the True Mean
Two methods were used to compute the upper confidence limit (UCL) on the mean. The first is a parametric method that assumes a normal distribution. The second is the Chebyshev method, which requires no distributional assumption.

UCLs ON THE MEAN	
95% Parametric UCL	0.13676
95% Non-Parametric (Chebyshev) UCL	0.19039

Because the data do not appear to be normally distributed according to the goodness-of-fit test performed above, the non-parametric UCL (0.1904) may be a more accurate upper confidence limit on the true mean.

One-Sample t-Test
A one-sample t-test was performed to compare the sample mean to the action level. The null hypothesis used is that the true mean equals or exceeds the action level (AL). The t-test was conducted at the 5% significance level. The sample value *t* was computed using the following equation:

$$t = \frac{\bar{x} - AL}{SE}$$

where
x is the sample mean of the n=44 data,
AL is the action level or threshold (0.1),
SE is the standard error = (standard deviation) / (square root of n).

This t was then compared with the critical value $t_{0.95}$, where $t_{0.95}$ is the value of the t distribution with n-1=43 degrees of freedom for which the proportion of the distribution to the left of $t_{0.95}$ is 0.95. The null hypothesis will be rejected if $t < -t_{0.95}$.

ONE-SAMPLE t-TEST		
t-statistic	**Critical Value $t_{0.95}$**	**Null Hypothesis**
0.15493	1.6811	Cannot Reject

The test did not reject the null hypothesis that the mean value at the site exceeds the threshold, therefore conclude the true mean exceeds the threshold.

Because the data do not appear to be normally distributed, the MARSSIM Sign Test might be preferred over the One Sample t-Test. The following table represents the results of the MARSSIM Sign Test using the current data:

MARSSIM Sign Test		
Test Statistic (S+)	**95% Critical Value**	**Null Hypothesis**
36	27	Reject

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Appendix C

APPENDIX C
VSP EVALUATION TABLES
FALCON REFINERY
INGLESIDE, TEXAS

Table C-0
Summary of Sample Quantities

AOC	Media	Quantity of Discrete Phase I Samples	Additional Sample Number Basis: Human Health	Ecological	EA Judgmental Samples	Previous FSP Samples**	Proposed Quantity of Additional Samples[1]
AOC 1	Soil: Surface & Subsurface	41	0	0	14	0	14
	Sediment	2	Not Applicable	Not Applicable	0	0	0
	Groundwater	20	**16**	Not Applicable	10	0	10*
AOC 2	Soil: Surface & Subsurface	Composite Samples	Not Applicable	Not Applicable	3	4	7
	Groundwater	0	Not Applicable	Not Applicable	1	0	1*
AOC 3	Soil: Surface & Subsurface	7	5	**25**	0	0	25
	Sediment	44	0	0	4	0	4
	Surface Water	7	**29**	13	4	0	33
	Groundwater	0	Not Applicable	Not Applicable	3	0	3*
AOC 4	Soil: Surface & Subsurface	Composite Samples	Not Applicable	Not Applicable	0	5	5
	Groundwater	0	Not Applicable	Not Applicable	1	0	1*
AOC 5	Sediment	3	Not Applicable	Not Applicable	0	7	7
AOC 6	Soil: Surface & Subsurface	3	Not Applicable	Not Applicable	2	0	2
AOC 7	Soil: Surface & Subsurface	2	Not Applicable	Not Applicable	2	0	2

* : All monitoring wells locations will be decided based on best professional judgment, instead of using VSP locations

** : RI/FS Field Sampling Plan Addendum No.1a, TRC, March 21, 2011

1 : Proposed Quantity of Additional Samples = Maximum between Human Health and Ecological Samples + EA Judgmental Samples + Previous FSP Samples

APPENDIX C
VSP EVALUATION TABLES
FALCON REFINERY
INGLESIDE, TEXAS

Table C-1
Calculated Minimum Sample Number to Estimate Exposure Point Concentrations for Human Health Risk Evaluation

Constituent	Quantity of Phase I samples	Concentration (mg/kg)					VSP calculated quantity of samples	Statistical Power? [2]	Proposed quantity of additional samples to collect	Notes
		Bench-mark	Max	Mean	St Dev	Gray Region (Delta) [1]				
AOC-1: Surface Soil										
1,2,4-Trimethylbenzene	41	6.20E+01	3.20E-03	9.38E-04	5.90E-04	6.20E+01	2	Yes	None	
Acetone	41	6.10E+04	9.63E-02	8.19E-03	1.53E-02	6.10E+04	2	Yes	None	
Aluminum	41	7.70E+04	2.54E+04	5.73E+03	5.18E+03	7.13E+04	2	Yes	None	
Arsenic	41	3.90E-01	3.10E+00	1.25E+00	8.99E-01	8.56E-01	11	Yes	None	
Barium	41	1.50E+04	1.25E+03	1.28E+02	2.35E+02	1.49E+04	2	Yes	None	
Benzo(a)anthracene	41	1.50E-01	3.97E+00	2.12E-01	6.25E-01	3.13E-01	36	Yes	None	
Benzo(a)pyrene	41	1.50E-02	7.75E-01	1.12E-01	1.80E-01	9.67E-02	31	Yes	None	
Benzo(b)fluoranthene	41	1.50E-01	1.03E+00	1.35E-01	2.00E-01	9.99E-02	36	Yes	None	
Beryllium	41	1.60E+02	8.90E-01	1.98E-01	1.80E-01	1.60E+02	2	Yes	None	
bis(2-Ethylhexyl)phthalate	41	3.50E+01	5.50E-01	1.43E-01	1.71E-01	3.49E+01	2	Yes	None	
Cadmium	41	7.00E+01	1.10E+00	1.06E-01	1.81E-01	6.99E+01	2	Yes	None	
Chromium	41	3.30E+04	1.49E+01	4.98E+00	3.53E+00	3.30E+04	2	Yes	None	
Chromium - Hexavalent	41	2.90E-01	3.10E+00	7.99E-01	4.99E-01	5.09E-01	10	Yes	None	
Chrysene	41	1.50E+01	4.12E+01	1.33E+00	6.55E+00	1.37E+01	4	Yes	None	
Cobalt	41	2.30E+01	4.60E+00	1.29E+00	9.99E-01	2.17E+01	2	Yes	None	
Copper	41	3.10E+03	2.35E+01	4.11E+00	4.01E+00	3.10E+03	2	Yes	None	
Isopropylbenzene	41	2.10E+03	2.27E-02	1.57E-03	3.57E-03	2.10E+03	2	Yes	None	
Lead	41	4.00E+02	8.07E+01	1.43E+01	1.79E+01	3.86E+02	2	Yes	None	
Manganese	41	1.80E+03	2.10E+02	7.85E+01	5.58E+01	1.72E+03	2	Yes	None	
Mercury	41	1.00E+01	7.40E-01	3.15E-02	1.14E-01	9.97E+00	2	Yes	None	
Methylene chloride	40	5.60E+01	2.35E-02	4.31E-03	4.92E-03	5.60E+01	2	Yes	None	
Nickel	41	1.50E+03	9.30E+00	2.54E+00	2.09E+00	1.50E+03	2	Yes	None	
Phenanthrene	41	1.70E+03	2.06E+00	1.56E-01	3.41E-01	1.70E+03	2	Yes	None	
Pyrene	41	1.70E+03	1.58E+00	1.73E-01	2.81E-01	1.70E+03	2	Yes	None	
Toluene	41	5.00E+03	4.40E-03	9.74E-04	7.48E-04	5.00E+03	2	Yes	None	
Vanadium	41	3.90E+02	2.93E+01	7.64E+00	6.38E+00	3.82E+02	2	Yes	None	
Xylene (total)	41	6.30E+02	7.70E-03	2.89E-03	1.36E-03	6.30E+02	2	Yes	None	
Zinc	41	2.30E+04	2.32E+02	4.66E+01	4.66E+01	2.30E+04	2	Yes	None	
AOC-1:Surface Soil number of additional samples needed for Human Health Risk Evaluation									0	

APPENDIX C
VSP EVALUATION TABLES
FALCON REFINERY
INGLESIDE, TEXAS

Constituent	Quantity of Phase I samples	Concentration (mg/kg) Bench-mark	Max	Mean	St Dev	Gray Region (Delta) [1]	VSP calculated quantity of samples	Statistical Power? [2]	Proposed quantity of additional samples to collect	Notes
AOC-1: Subsurface Soil										
1,2,4-Trimethylbenzene	41	2.10E-02	1.40E-01	6.08E-03	2.47E-02	1.49E-02	25	Yes	None	
Acetone	41	2.40E+00	2.49E-01	2.76E-02	4.12E-02	2.37E+00	2	Yes	None	
Aluminum	41	2.30E+04	1.38E+04	3.55E+03	3.36E+03	1.94E+04	2	Yes	None	
Arsenic	41	1.30E-03	2.20E+00	6.36E-01	5.84E-01	6.35E-01	9	Yes	None	
Barium	41	1.20E+02	9.87E+01	3.05E+01	2.53E+01	8.95E+01	3	Yes	None	
Beryllium	41	1.30E+01	4.20E-01	1.14E-01	1.02E-01	1.29E+01	2	Yes	None	
Carbon disulfide	41	2.10E-01	4.10E-03	1.01E-03	6.86E-04	2.09E-01	2	Yes	None	
Chromium	41	NA	1.50E+01	3.09E+00	2.69E+00	NA	NA	NA	NA	
Chromium, Hexavalent	41	5.90E-04	1.60E+00	6.77E-01	2.49E-01	6.76E-01	3	Yes	None	
Cobalt	41	2.10E-01	1.90E+00	5.59E-01	4.99E-01	3.49E-01	19	Yes	None	
Copper	41	2.20E+01	5.90E+00	1.48E+00	1.26E+00	2.05E+01	2	Yes	None	
Diethyl phthalate	41	4.70E+00	3.10E-01	4.58E-02	5.08E-02	4.65E+00	2	Yes	None	
Lead	41	4.00E+02	2.60E+01	3.75E+00	3.96E+00	3.96E+02	2	Yes	None	
Manganese	41	2.10E+01	2.41E+02	4.28E+01	5.37E+01	2.69E+01	36	Yes	None	
Mercury	41	3.30E-02	5.90E-01	2.48E-02	9.18E-02	4.59E-02	36	Yes	None	
Methylene chloride	41	2.50E-03	9.99E-02	7.38E-03	1.59E-02	7.97E-03	36	Yes	None	
Nickel	41	2.00E+01	5.90E+00	1.33E+00	1.42E+00	1.87E+01	2	Yes	None	
Vanadium	41	7.80E+01	1.37E+01	3.96E+00	3.40E+00	7.40E+01	2	Yes	None	
Xylene (total)	41	1.90E-01	2.17E-02	3.14E-03	3.42E-03	1.87E-01	2	Yes	None	
Zinc	41	2.90E+02	2.48E+01	7.41E+00	5.99E+00	2.83E+02	2	Yes	None	
AOC-1:Subsurface Soil number of additional samples needed for Human Health Risk Evaluation									0	
Total AOC-1: Soil number of additional samples needed for Human Health Risk Evaluation									**0**	

1 - Delta = the greater value between the absolue value of the difference between the sample mean and the benchmark, or one=half the sample standard deviation. Delta chosen in accordance with VSP User Guide, Version 5.0, September 2007, page 3.7, "Determining a reasonable value for the size of the gray region calls for professional judgment and cost/benefit evaluation." alpha = 0.05 and beta = 0.1

2 - statistical power is achieved when either the null hypothesis is rejected or the sample size equation indicates a sample size less than the number of Phase I samples, in this case we are focusing on the number of samples

* The wetlands present in AOC-3 are a mixture of freshwater and saltwater wetlands. For the purposes of the VSP analysis, the lowest values between freshwater and saltwater ecological screening values were chosen.

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VSP EVALUATION TABLES
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Table C-2
Calculated Minimum Sample Number to Estimate Exposure Point Concentrations for Ecological Risk Evaluation

Constituent	Quantity of Phase I samples	Concentration (mg/kg) Bench-mark	Max	Mean	St Dev	Gray Region (Delta) [1]	VSP calculated quantity of samples	Statistical Power? [2]	Proposed quantity of additional samples to collect	Notes
AOC-1: Surface Soil										
Arsenic	41	1.80E+01	3.10E+00	1.25E+00	8.99E-01	1.68E+01	2	Yes	None	
Barium	41	3.30E+02	1.25E+03	1.28E+02	2.35E+02	2.02E+02	13	Yes	None	
Beryllium	41	2.10E+01	8.90E-01	1.98E-01	1.80E-01	2.08E+01	2	Yes	None	
Cadmium	41	3.60E-01	1.10E+00	1.06E-01	1.81E-01	2.54E-01	6	Yes	None	
Chromium	41	NA	1.49E+01	4.98E+00	3.53E+00	NA	NA	NA	NA	
Cobalt	41	1.30E+01	4.60E+00	1.29E+00	9.99E-01	1.17E+01	2	Yes	None	
Copper	41	2.80E+01	2.35E+01	4.11E+00	4.01E+00	2.39E+01	2	Yes	None	
Lead	41	1.10E+01	8.07E+01	1.43E+01	1.79E+01	8.94E+00	36	Yes	None	
Manganese	41	2.20E+02	2.10E+02	7.85E+01	5.58E+01	1.41E+02	3	Yes	None	
Mercury	41	1.00E-01	7.40E-01	3.15E-02	1.14E-01	6.85E-02	26	Yes	None	
Nickel	41	3.80E+01	9.30E+00	2.54E+00	2.09E+00	3.55E+01	2	Yes	None	
Toluene	41	NA	4.40E-03	9.74E-04	7.48E-04	NA	NA	NA	NA	
Vanadium	41	7.80E+00	2.93E+01	7.64E+00	6.38E+00	3.19E+00	36	Yes	None	
Zinc	41	4.60E+01	2.32E+02	4.66E+01	4.66E+01	2.33E+01	36	Yes	None	
AOC-1:Surface Soil number of additional samples needed for Human Health Risk Evaluation									0	

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Constituent	Quantity of Phase I samples	Concentration (mg/kg)					VSP calculated quantity of samples	Statistical Power? [2]	Proposed quantity of additional samples to collect	Notes
		Bench-mark	Max	Mean	St Dev	Gray Region (Delta) [1]				
AOC-1: Subsurface Soil										
Arsenic	41	1.80E+01	2.20E+00	6.36E-01	5.84E-01	1.74E+01	2	Yes	None	
Barium	41	3.30E+02	9.87E+01	3.05E+01	2.53E+01	2.99E+02	2	Yes	None	
Beryllium	41	2.10E+01	4.20E-01	1.14E-01	1.02E-01	2.09E+01	2	Yes	None	
Chromium	41	NA	1.50E+01	3.09E+00	2.69E+00	NA	NA	NA	NA	
Cobalt	41	1.30E+01	1.90E+00	5.59E-01	4.99E-01	1.24E+01	2	Yes	None	
Copper	41	2.80E+01	5.90E+00	1.48E+00	1.26E+00	2.65E+01	2	Yes	None	
Diethyl phthalate	41	NA	3.10E-01	4.58E-02	5.08E-02	NA	NA	NA	NA	
Lead	41	1.10E+01	2.60E+01	3.75E+00	3.96E+00	7.25E+00	4	Yes	None	
Manganese	41	2.20E+02	2.41E+02	4.28E+01	5.37E+01	1.77E+02	3	Yes	None	
Mercury	41	1.00E-01	5.90E-01	2.48E-02	9.18E-02	7.52E-02	15	Yes	None	
Nickel	41	3.80E+01	5.90E+00	1.33E+00	1.42E+00	3.67E+01	2	Yes	None	
Vanadium	41	7.80E+00	1.37E+01	3.96E+00	3.40E+00	3.84E+00	9	Yes	None	
Zinc	41	4.60E+01	2.48E+01	7.41E+00	5.99E+00	3.86E+01	2	Yes	None	
AOC-1:Subsurface Soil number of additional samples needed for Human Health Risk Evaluation									0	
Total AOC-1: Soil number of additional samples needed for Human Health Risk Evaluation									**0**	

1 - Delta = the greater value between the absolue value of the difference between the sample mean and the benchmark, or one=half the sample standard deviation. Delta chosen in accordance with VSP User Guide, Version 5.0, September 2007, page 3.7, "Determining a reasonable value for the size of the gray region calls for professional judgment and cost/benefit evaluation." alpha = 0.05 and beta = 0.1

2 - statistical power is achieved when either the null hypothesis is rejected or the sample size equation indicates a sample size less than the number of Phase I samples, in this case we are focusing on the number of samples

* The wetlands present in AOC-3 are a mixture of freshwater and saltwater wetlands. For the purposes of the VSP analysis, the lowest values between freshwater and saltwater ecological screening values were chosen.

Table C-3
Calculated Minimum Sample Number to Estimate Exposure Point Concentrations for Human Health Risk Evaluation

Constituent	Quantity of Phase I samples	Concentration (mg/L) Bench-mark	Max	Mean	St Dev	Gray Region (Delta) [1]	VSP calculated quantity of samples	Statistical Power? [2]	Proposed quantity of additional samples to collect	Notes
AOC-1: Ground Water- Human Health										
1-Methylnaphthalene	20	9.70E-04	6.47E-02	5.34E-03	1.45E-02	7.25E-03	36	No	16	
Acetone	20	1.20E+01	8.90E-03	4.95E-03	2.27E-03	1.20E+01	2	Yes	None	
Aluminum	20	1.60E+01	4.28E+00	5.03E-01	9.76E-01	1.55E+01	2	Yes	None	
Arsenic	20	4.50E-05	4.37E-02	8.44E-03	1.03E-02	8.39E-03	15	Yes	None	
Barium	20	2.00E+00	5.57E-01	1.82E-01	1.40E-01	1.82E+00	2	Yes	None	
Benzene	20	3.90E-04	1.45E-02	1.12E-03	3.22E-03	1.61E-03	36	No	16	
bis(2-Ethylhexyl)phthalate	20	7.10E-05	6.63E-03	1.27E-03	1.36E-03	1.20E-03	13	Yes	None	
Cyclohexane	20	NA	3.23E-02	1.93E-03	7.15E-03	NA	NA	NA	NA	
Ethylbenzene	20	1.30E-03	8.00E-03	1.06E-03	1.96E-03	9.78E-04	36	No	16	
Lead	20	1.50E-02	1.95E-02	3.76E-03	4.62E-03	1.12E-02	3	Yes	None	
Manganese	20	3.20E-01	4.12E+00	8.16E-01	9.84E-01	4.96E-01	36	No	16	
Naphthalene	20	1.40E-04	1.63E-01	1.17E-02	3.65E-02	1.82E-02	36	No	16	
Nickel	20	3.00E-01	5.16E-02	5.20E-03	1.12E-02	2.95E-01	2	Yes	None	
Thallium	20	1.60E-04	6.70E-03	3.41E-03	1.81E-03	3.25E-03	5	Yes	None	
Vanadium	20	7.80E-02	1.67E-02	2.71E-03	4.35E-03	7.53E-02	2	Yes	None	
Zinc	20	4.70E+00	1.96E-01	3.20E-02	4.15E-02	4.67E+00	2	Yes	None	
AOC-1:Ground water number of additional samples needed for Human Health Risk Evaluation									16	

1 - Delta = the greater value between the absolue value of the difference between the sample mean and the benchmark, or one=half the sample standard deviation. Delta chosen in accordance with VSP User Guide, Version 5.0, September 2007, page 3.7, "Determining a reasonable value for the size of the gray region calls for professional judgment and cost/benefit evaluation." alpha = 0.05 and beta = 0.1

2 - statistical power is achieved when either the null hypothesis is rejected or the sample size equation indicates a sample size less than the number of Phase I samples, in this case we are focusing on the number of samples

* The wetlands present in AOC-3 are a mixture of freshwater and saltwater wetlands. For the purposes of the VSP analysis, the lowest values between freshwater and saltwater ecological screening values were chosen.

Table C-4
Calculated Minimum Sample Number to Estimate Exposure Point Concentrations for Human Health Risk Evaluation

Constituent	Quantity of Phase I samples	Concentration (mg/kg)					VSP calculated quantity of samples	Statistical Power? [2]	Proposed quantity of additional samples to collect	Notes
		Bench-mark	Max	Mean	St Dev	Gray Region (Delta) [1]				
AOC-3: Surface Soil										
Aluminum	7	7.70E+04	6.02E+03	4.03E+03	1.31E+03	7.30E+04	2	Yes	None	
Arsenic	7	3.90E-01	2.50E+00	1.18E+00	5.94E-01	7.88E-01	7	Yes	None	
Barium	7	1.50E+04	6.30E+02	1.90E+02	2.10E+02	1.48E+04	2	Yes	None	
Beryllium	7	1.60E+02	2.40E-01	1.79E-01	5.66E-02	1.60E+02	2	Yes	None	
Chromium	7	3.30E+04	5.90E+00	4.04E+00	1.44E+00	3.30E+04	2	Yes	None	
Cobalt	7	2.30E+01	1.35E+00	9.80E-01	3.14E-01	2.20E+01	2	Yes	None	
Copper	7	3.10E+03	4.60E+00	3.56E+00	8.06E-01	3.10E+03	2	Yes	None	
Lead	7	4.00E+02	1.35E+01	6.67E+00	3.39E+00	3.93E+02	2	Yes	None	
Manganese	7	1.80E+03	2.26E+02	1.07E+02	5.56E+01	1.69E+03	2	Yes	None	
Mercury	7	1.00E+01	2.20E-02	1.19E-02	6.24E-03	9.99E+00	2	Yes	None	
Nickel	7	1.50E+03	2.50E+00	1.83E+00	6.07E-01	1.50E+03	2	Yes	None	
Vanadium	7	3.90E+02	8.40E+00	5.93E+00	1.76E+00	3.84E+02	2	Yes	None	
Zinc	7	2.30E+04	3.46E+02	1.18E+02	1.35E+02	2.29E+04	2	Yes	None	
AOC-3:Surface Soil number of additional samples needed for Human Health Risk Evaluation									0	

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Constituent	Quantity of Phase I samples	Concentration (mg/kg)					VSP calculated quantity of samples	Statistical Power? [2]	Proposed quantity of additional samples to collect	Notes
		Bench-mark	Max	Mean	St Dev	Gray Region (Delta) [1]				
AOC-3: Subsurface Soil										
Acetone	7	2.40E+00	8.04E-02	2.87E-02	2.44E-02	2.37E+00	2	Yes	None	
Aluminum	7	2.30E+04	4.60E+03	3.63E+03	7.77E+02	1.94E+04	2	Yes	None	
Arsenic	7	1.30E-03	2.40E+00	1.12E+00	6.41E-01	1.12E+00	5	Yes	None	
Barium	7	1.20E+02	2.09E+02	5.52E+01	6.88E+01	6.48E+01	12	No	5	
Beryllium	7	1.30E+01	2.00E-01	1.61E-01	3.86E-02	1.28E+01	2	Yes	None	
Chromium	7	3.30E+04	4.00E+00	3.29E+00	6.49E-01	3.30E+04	2	Yes	None	
Cobalt	7	2.10E-01	1.10E+00	8.46E-01	2.00E-01	6.36E-01	3	Yes	None	
Copper	7	2.20E+01	5.00E+00	2.44E+00	1.20E+00	1.96E+01	2	Yes	None	
Lead	7	4.00E+02	4.30E+00	2.99E+00	6.39E-01	3.97E+02	2	Yes	None	
Manganese	7	2.10E+01	1.14E+02	7.28E+01	3.62E+01	5.18E+01	6	Yes	None	
Mercury	7	3.30E-02	3.40E-02	1.37E-02	1.39E-02	1.93E-02	6	Yes	None	
Nickel	7	2.00E+01	2.30E+00	1.63E+00	4.03E-01	1.84E+01	2	Yes	None	
Toluene	7	5.90E-01	1.80E-03	1.29E-03	5.11E-04	5.89E-01	2	Yes	None	
Vanadium	7	7.80E+01	7.90E+00	5.33E+00	1.21E+00	7.27E+01	2	Yes	None	
Zinc	7	2.90E+02	3.58E+01	1.66E+01	9.15E+00	2.73E+02	2	Yes	None	
AOC-3:Subsurface Soil number of additional samples needed for Human Health Risk Evaluation									5	
Total AOC-3: Soil number of additional samples needed for Human Health Risk Evaluation									**5**	

1 - Delta = the greater value between the absolue value of the difference between the sample mean and the benchmark, or one=half the sample standard deviation. Delta chosen in accordance with VSP User Guide, Version 5.0, September 2007, page 3.7, "Determining a reasonable value for the size of the gray region calls for professional judgment and cost/benefit evaluation." alpha = 0.05 and beta = 0.1

2 - statistical power is achieved when either the null hypothesis is rejected or the sample size equation indicates a sample size less than the number of Phase I samples, in this case we are focusing on the number of samples

* The wetlands present in AOC-3 are a mixture of freshwater and saltwater wetlands. For the purposes of the VSP analysis, the lowest values between freshwater and saltwater ecological screening values were chosen.

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Table C-5
Calculated Minimum Sample Number to Estimate Exposure Point Concentrations for Ecological Risk Evaluation

Constituent	Quantity of Phase I samples	Concentration (mg/kg)					VSP calculated quantity of samples	Statistical Power? [2]	Proposed quantity of additional samples to collect	Notes
		Bench-mark	Max	Mean	St Dev	Gray Region (Delta) [1]				
AOC-3: Surface Soil										
Arsenic	7	1.80E+01	2.50E+00	1.18E+00	5.94E-01	1.68E+01	2	Yes	None	
Barium	7	3.30E+02	6.30E+02	1.90E+02	2.10E+02	1.40E+02	21	No	14	
Beryllium	7	2.10E+01	2.40E-01	1.79E-01	5.66E-02	2.08E+01	2	Yes	None	
Chromium	7	NA	5.90E+00	4.04E+00	1.44E+00	NA	NA	NA	NA	
Cobalt	7	1.30E+01	1.35E+00	9.80E-01	3.14E-01	1.20E+01	2	Yes	None	
Copper	7	2.80E+01	4.60E+00	3.56E+00	8.06E-01	2.44E+01	2	Yes	None	
Lead	7	1.10E+01	1.35E+01	6.67E+00	3.39E+00	4.33E+00	7	Yes	None	
Manganese	7	2.20E+02	2.26E+02	1.07E+02	5.56E+01	1.13E+02	4	Yes	None	
Mercury	7	1.00E-01	2.20E-02	1.19E-02	6.24E-03	8.81E-02	2	Yes	None	
Nickel	7	3.80E+01	2.50E+00	1.83E+00	6.07E-01	3.62E+01	2	Yes	None	
Vanadium	7	7.80E+00	8.40E+00	5.93E+00	1.76E+00	1.87E+00	9	No	2	
Zinc	7	4.60E+01	3.46E+02	1.18E+02	1.35E+02	7.19E+01	32	No	25	
AOC-3:Surface Soil number of additional samples needed for Ecological Risk Evaluation									25	

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Constituent	Quantity of Phase I samples	Concentration (mg/kg)					VSP calculated quantity of samples	Statistical Power? [2]	Proposed quantity of additional samples to collect	Notes
		Bench-mark	Max	Mean	St Dev	Gray Region (Delta) [1]				
AOC-3: Subsurface Soil										
Arsenic	7	1.80E+01	2.40E+00	1.12E+00	6.41E-01	1.69E+01	2	Yes	None	
Barium	7	3.30E+02	2.09E+02	5.52E+01	6.88E+01	2.75E+02	2	Yes	None	
Beryllium	7	2.10E+01	2.00E-01	1.61E-01	3.86E-02	2.08E+01	2	Yes	None	
Chromium	7	NA	4.00E+00	3.29E+00	6.49E-01	NA	NA	NA	NA	
Cobalt	7	1.30E+01	1.10E+00	8.46E-01	2.00E-01	1.22E+01	2	Yes	None	
Copper	7	2.80E+01	5.00E+00	2.44E+00	1.20E+00	2.56E+01	2	Yes	None	
Lead	7	1.10E+01	4.30E+00	2.99E+00	6.39E-01	8.01E+00	2	Yes	None	
Manganese	7	2.20E+02	1.14E+02	7.28E+01	3.62E+01	1.47E+02	2	Yes	None	
Mercury	7	1.00E-01	3.40E-02	1.37E-02	1.39E-02	8.63E-02	2	Yes	None	
Nickel	7	3.80E+01	2.30E+00	1.63E+00	4.03E-01	3.64E+01	2	Yes	None	
Toluene	7	NA	1.80E-03	1.29E-03	5.11E-04	NA	NA	NA	NA	
Vanadium	7	7.80E+00	7.90E+00	5.33E+00	1.21E+00	2.47E+00	4	Yes	None	
Zinc	7	4.60E+01	3.58E+01	1.66E+01	9.15E+00	2.94E+01	3	Yes	None	
AOC-3:Subsurface Soil number of additional samples needed for Ecological Risk Evaluation									0	
Total AOC-3: Soil number of additional samples needed for Ecological Risk Evaluation									**25**	

1 - Delta = the greater value between the absolue value of the difference between the sample mean and the benchmark, or one=half the sample standard deviation. Delta chosen in accordance with VSP User Guide, Version 5.0, September 2007, page 3.7, "Determining a reasonable value for the size of the gray region calls for professional judgment and cost/benefit evaluation." alpha = 0.05 and beta = 0.1

2 - statistical power is achieved when either the null hypothesis is rejected or the sample size equation indicates a sample size less than the number of Phase I samples, in this case we are focusing on the number of samples

* The wetlands present in AOC-3 are a mixture of freshwater and saltwater wetlands. For the purposes of the VSP analysis, the lowest values between freshwater and saltwater ecological screening values were chosen.

Table C-6

Calculated Minimum Sample Number to Estimate Exposure Point Concentrations for Human Health and Ecological Risk Evaluation

Constituent	Quantity of Phase I samples	Concentration (mg/L)					VSP calculated quantity of samples	Statistical Power? [2]	Proposed quantity of additional samples to collect	Notes
		Bench-mark*	Max	Mean	St Dev	Gray Region (Delta) [1]				
AOC-3: Surface Water- Human Health										
Antimony	7	5.60E-03	4.20E-03	2.96E-03	1.25E-03	2.64E-03	4	Yes	None	
Chromium - Hexavalent	7	6.20E-02	1.60E-02	6.86E-03	6.12E-03	5.51E-02	2	Yes	None	
Lead	7	1.15E-03	1.02E-02	4.46E-03	2.87E-03	3.31E-03	8	No	1	
Manganese	7	5.00E-02	1.94E-01	5.85E-02	7.90E-02	3.95E-02	36	No	29	
Zinc	7	7.40E+00	7.58E-02	2.98E-02	2.07E-02	7.37E+00	2	Yes	None	
AOC-3:Surface water number of additional samples needed for Human Health Risk Evaluation									29	
AOC-3: Surface Water- Ecological										
Barium	7	1.60E+01	7.68E-01	4.77E-01	2.43E-01	1.55E+01	2	Yes	None	
Chromium - Hexavalent	7	5.00E-02	1.60E-02	6.86E-03	6.12E-03	4.31E-02	2	Yes	None	
Lead	7	2.50E-03	1.02E-02	4.46E-03	2.87E-03	1.96E-03	20	No	13	
Zinc	7	8.10E-02	7.58E-02	2.98E-02	2.07E-02	5.12E-02	3	Yes	None	
AOC-3:Surface water number of additional samples needed for Ecological Risk Evaluation									13	
Total AOC-3: Surface water of additional samples needed for Human Health and Ecological Risk Evaluation									**29**	

1 - Delta = the greater value between the absolue value of the difference between the sample mean and the benchmark, or one=half the sample standard deviation. Delta chosen in accordance with VSP User Guide, Version 5.0, September 2007, page 3.7, "Determining a reasonable value for the size of the gray region calls for professional judgment and cost/benefit evaluation." alpha = 0.05 and beta = 0.1

2 - statistical power is achieved when either the null hypothesis is rejected or the sample size equation indicates a sample size less than the number of Phase I samples, in this case we are focusing on the number of samples

* The wetlands present in AOC-3 are a mixture of freshwater and saltwater wetlands. For the purposes of the VSP analysis, the lowest values between freshwater and saltwater ecological screening values were chosen.

Table C-7
Calculated Minimum Sample Number to Estimate Exposure Point Concentrations for Human Health and Ecological Risk Evaluation

Constituent	Quantity of Phase I samples	Concentration (mg/kg) Bench-mark	Max	Mean	St Dev	Gray Region (Delta) [1]	VSP calculated quantity of samples	Statistical Power? [2]	Proposed quantity of additional samples to collect	Notes
AOC-3: Sediment- Human Health										
1,2,4-Trimethylbenzene	44	6.20E+01	4.90E-03	1.03E-03	9.03E-04	6.20E+01	2	Yes	None	
Acetone	44	6.10E+04	6.68E-01	5.61E-02	1.08E-01	6.10E+04	2	Yes	None	
Aluminum	44	7.70E+04	3.59E+04	6.67E+03	8.08E+03	7.03E+04	2	Yes	None	
Arsenic	44	3.90E-01	1.73E+01	2.53E+00	2.99E+00	2.14E+00	19	Yes	None	
Barium	44	1.50E+04	1.70E+03	1.89E+02	3.03E+02	1.48E+04	2	Yes	None	
Beryllium	44	1.60E+02	1.40E+00	2.72E-01	3.07E-01	1.60E+02	2	Yes	None	
bis(2-Ethylhexyl)phthalate	44	1.30E+01	7.29E-01	1.03E-01	1.33E-01	1.29E+01	2	Yes	None	
Cadmium	44	7.00E+01	6.70E-01	1.20E-01	1.34E-01	6.99E+01	2	Yes	None	
Carbon disulfide	44	8.20E+02	2.41E-02	2.53E-03	4.43E-03	8.20E+02	2	Yes	None	
Chromium	44	3.30E+04	2.99E+01	6.35E+00	7.12E+00	3.30E+04	2	Yes	None	
Cobalt	44	2.30E+01	1.04E+01	1.76E+00	2.15E+00	2.12E+01	2	Yes	None	
Copper	44	3.10E+03	5.71E+01	7.55E+00	1.08E+01	3.09E+03	2	Yes	None	
Hexane	44	NA	8.60E-03	1.35E-03	1.54E-03	NA	NA	NA	NA	
Lead	44	4.00E+02	3.41E+01	8.56E+00	7.71E+00	3.91E+02	2	Yes	None	
Manganese	44	1.80E+03	5.88E+02	1.42E+02	1.47E+02	1.66E+03	2	Yes	None	
Mercury	44	1.00E+01	1.10E-01	1.55E-02	1.83E-02	9.98E+00	2	Yes	None	
Methyl ethyl ketone	44	2.80E+04	1.35E-01	1.10E-02	2.08E-02	2.80E+04	2	Yes	None	
Methylene chloride	44	5.60E+01	1.99E-02	5.05E-03	2.87E-03	5.60E+01	2	Yes	None	
Nickel	44	1.50E+03	2.35E+01	3.91E+00	4.87E+00	1.50E+03	2	Yes	None	
Selenium	44	3.90E+02	2.20E+00	2.95E-01	3.84E-01	3.90E+02	2	Yes	None	
Silver	44	3.90E+02	1.30E+00	1.31E-01	2.46E-01	3.90E+02	2	Yes	None	
Toluene	44	5.00E+03	3.76E-02	2.01E-03	5.57E-03	5.00E+03	2	Yes	None	
Vanadium	44	3.90E+02	5.89E+01	1.02E+01	1.23E+01	3.80E+02	2	Yes	None	
Zinc	44	2.30E+04	8.96E+02	1.69E+02	2.27E+02	2.28E+04	2	Yes	None	
AOC-3:Sediment number of additional samples needed for Human Health Risk Evaluation									0	

APPENDIX C
VSP EVALUATION TABLES
FALCON REFINERY
INGLESIDE, TEXAS

Constituent	Quantity of Phase I samples	Concentration (mg/kg)					VSP calculated quantity of samples	Statistical Power? [2]	Proposed quantity of additional samples to collect	Notes
		Bench-mark	Max	Mean	St Dev	Gray Region (Delta) [1]				
AOC-3: Sediment- Ecological										
Arsenic	44	9.80E+00	1.73E+01	2.53E+00	2.99E+00	7.27E+00	3	Yes	None	
bis(2-Ethylhexyl)phthalate	44	1.00E-01	7.29E-01	1.03E-01	1.33E-01	6.64E-02	36	Yes	None	
Cadmium	44	9.90E-01	6.70E-01	1.20E-01	1.34E-01	8.70E-01	2	Yes	None	
Chromium	44	NA	2.99E+01	6.35E+00	7.12E+00	NA	NA	NA	NA	
Copper	44	3.20E+01	5.71E+01	7.55E+00	1.08E+01	2.45E+01	4	Yes	None	
Lead	44	3.60E+01	3.41E+01	8.56E+00	7.71E+00	2.74E+01	3	Yes	None	
Mercury	44	1.80E-01	1.10E-01	1.55E-02	1.83E-02	1.64E-01	2	Yes	None	
Methylene chloride	44	1.80E-02	1.99E-02	5.05E-03	2.87E-03	1.29E-02	2	Yes	None	
Nickel	44	2.30E+01	2.35E+01	3.91E+00	4.87E+00	1.91E+01	2	Yes	None	
Silver	44	5.00E-01	1.30E+00	1.31E-01	2.46E-01	3.69E-01	6	Yes	None	
Toluene	44	NA	3.76E-02	2.01E-03	5.57E-03	NA	NA	NA	NA	
Zinc	44	1.21E+02	8.96E+02	1.69E+02	2.27E+02	1.14E+02	36	Yes	None	
r of additional samples needed for Ecological Risk Evaluation									0	
Total AOC-3: Sediment number of additional samples needed for Human Health and Ecological Risk Evaluation									**0**	

1 - Delta = the greater value between the absolue value of the difference between the sample mean and the benchmark, or one=half the sample standard deviation. Delta chosen in accordance with VSP User Guide, Version 5.0, September 2007, page 3.7, "Determining a reasonable value for the size of the gray region calls for professional judgment and cost/benefit evaluation." alpha = 0.05 and beta = 0.1

2 - statistical power is achieved when either the null hypothesis is rejected or the sample size equation indicates a sample size less than the number of Phase I samples, in this case we are focusing on the number of samples

* The wetlands present in AOC-3 are a mixture of freshwater and saltwater wetlands. For the purposes of the VSP analysis, the lowest values between freshwater and saltwater ecological screening values were chosen.

Appendix D

APPENDIX D
TENTATIVE DETERMINATION OF APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

ARAR	Citation (If Available)	Description	Applicability
Chemical Specific ARARs			
Federal Safe Drinking Water Act, Primary Drinking Water Standards (MCLs)	40 CFR 141,143	Establishes health-based standards for public water systems. It is applicable where contaminated ground water is or may be used for drinking water.	ARAR applies because Austin Chalk, Buda Limestone, and Edwards Aquifers are primary or potential drinking water sources.
Media Cleanup Requirements for Risk Reduction	30 TAC §335	This section specifies the requirements for reestablishing cleanup levels for air, ground water, and soil, including use of media-specific adjustments.	TBC for establishing site cleanup levels for contaminated air, ground water, and soil.
Location Specific			
Location Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities	40 CFR 264.18	These regulations prohibit new treatment, storage, or disposal of hazardous waste within 200 feet of a fault displaced in Holocene time, and require that a facility must be designed and maintained to avoid washout if located within a 100-year floodplain.	ARAR applies because site contains faults that may be displaced in Holocene time. Additionally, parts of the site are within a 100-year floodplain.
Floodplain Management	Executive Order 11988; 40 CFR 6.302 and Appendix A	Requires federal agencies to evaluate the potential affects of actions they may take in a floodplain to avoid adverse impacts in a floodplain.	ARAR applies because parts of the site are within a 100-year floodplain.
Texas Risk Reduction Program	30 TAC § 350	This program provides a consistent corrective action process directed toward protection of human health and the environment balanced with the economic welfare of the citizens of this state. TRRP classifies ground water resources into three classes of ground water, which have protective concentration level (PCL) designations for COCs. TRRP also defines PCL for surface and subsurface soils.	TBC - Austin Chalk, Buda Limestone, and Edwards Aquifer are classified as a primary or potential ground water resources. Additionally, COCs are present in the surface and subsurface soils.
Texas Risk Reduction Program - Ground Water Classification	30 TAC § 350.52 (1)(A)	Groundwater-bearing units within ½ mile of public drinking water supply wells are Class 1 groundwater resources if they can can contribute COCs; considerations include COC chemical properties, the local hydrogeology, and the construction of the wells.	TBC - Water supply well USGS-50, which is completed in the Edwards Aquifer, has reported detections of PCE in groundwater, and this well is located about 2500 feet southeast of AOI 1/Source Area 1. Based on the COCs (i.e., PCE is a DNAPL), the hyrogeologic setting, (i.e.,karst formations), and construction of wells (i.e., surface casing and open hole), the Austin Chalk, Buda Limestone, and Edwards groundwater-bearing units are all Class 1 groundwater resources.
Action Specific			
Water			
Federal Water Pollution Control Act	40 CFR 403	Establishes responsibilities of Federal, State, and local government, industry and the public to implement National Pretreatment Standards to control pollutants which pass through or interfere with treatment processes in Publicly Owned Treatment Works (POTWs) or which may contaminate sewage sludge.	ARAR applies because extracted ground water may be delivered to POTWs.
Federal Safe Drinking Water Act	40 CFR 149	Provides for a federally implemented sole source aquifer program, which prohibits federal funds from being expended on projects that may contaminate the sole or principal source of drinking water for a given area.	ARAR applies because the Edwards Aquifer has been designated by EPA as a Sole Source Aquifer
Ground Water Restoration	Texas Water Code 26.401	Requires ground water quality to be restored, if feasible.	ARAR applies because RAO for ground water is to restore through remediation processes.
Texas Department of Licensing and Regulation	16 TAC § 76.1000-1009	Regulations regarding the installation and abandonment of ground water wells.	TBC - Remedial alternatives include the installation of ground water wells. TBC because variances are allowed.
Air			
National Primary and Secondary Ambient Air Quality Standards (NAAQS)	40 CFR 50.4, 50.6, 50.8, 50.9, 50.11, 50.12	NAAQS define levels of air quality to protect the public health or the public welfare from any known or anticipated adverse effects of a federally regulated pollutant. NAAQS for sulfur dioxide, nitrogen dioxide, and carbon monoxide apply to incineration.	ARAR may apply if incineration is used during remedial action.

APPENDIX D
TENTATIVE DETERMINATION OF APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

ARAR	Citation (If Available)	Description	Applicability
Texas Clean Air Act	Texas Health and Safety Code Section 382	The policy of this state and the purpose of this chapter are to safeguard the state's air resources from pollution by controlling or abating air pollution and emissions of air contaminants, consistent with the protection of public health, general welfare, and physical property.	ARAR applies if remediation includes emissions.

APPENDIX D
TENTATIVE DETERMINATION OF APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

ARAR	Citation (If Available)	Description	Applicability
Texas Administrative Code - Air Quality	30 TAC § 101.4	No person shall discharge from any source whatsoever one or more air contaminants or combinations thereof, in such concentration and of such duration as are or may tend to be injurious to or to adversely affect human health or welfare, animal life, vegetation, or property, or as to interfere with the normal use and enjoyment of animal life, vegetation, or property.	ARAR applies if remediation includes emissions.
Texas Administrative Code	30 TAC § 115	Control of air pollution from volatile organic compounds.	ARAR applies if remediation includes emissions.
Soil			
Relocation of Soils Containing Chemicals of Concern for Reuse Purposes	30 TAC § 350.36	A person must comply with this section when relocating soils for reuse purposes from an affected property (on-site or off-site) which is undergoing or has completed a response action under Remedy Standard A or B and the soils contain COCs in excess of naturally occurring background concentrations.	ARAR applies because a possible remedial alternative for soil treatment is excavation and off-site disposal.
Waste			
Criteria for Identifying the Characteristics of Hazardous Waste and for Listing Hazardous Waste	40 CFR 261	Provides the criteria for identifying a characteristic or listed waste. Solid waste is a hazardous waste if it exhibits any of the characteristics of ignitability, corrosivity, reactivity, and toxicity or if it is a listed waste. Applicable to off site waste disposal.	ARAR applies for possible off-site disposal of excavated soil.
Standards Applicable to Generators of Hazardous Waste	40 CFR 262	Provides requirements for preparation of waste manifests, waste packaging, labeling and handling.	ARAR applies for possible off-site disposal of excavated soil.
Standards Applicable to Transporters of Hazardous Waste	40 CFR Part 263, 30 TAC 335.91	Requires that hazardous material to be transported off site be labeled and placarded according to the regulations and that contractors who transport the hazardous waste provide proper documentation.	ARAR applies for possible off-site disposal of excavated soil.
Land Disposal Restrictions	40 CFR 268	Restricts the land disposal of most hazardous wastes, and specified specific treatment standards that must be met before these wastes can be land disposed.	ARAR applies for possible off-site disposal of excavated soil.
Procedures of Planning and Implementing Off-site Response Actions	40 CFR 300.400	Hazardous waste generated from CERCLA cleanups must go to RCRA permitted treatment, storage, and disposal facilities that are in compliance with RCRA and state rules and that do not have releases to the environment.	ARAR applies because this site is a CERCLA cleanup.
Spill Prevention and Control	30 TAC § 327.4	Defines the reportable quantities in the event of a spill or release to environment.	ARAR applies to possible releases or spills to the environment during remedial activities.
Waste Classification	30 TAC § 335.505, 30 TAC § 335.508	Provides procedure for implementation of Texas waste notification system and establishes standards for classification of industrial solid waste managed in Texas, including Class 1, Class 2, and Class 3 wastes.	ARAR applies because waste will be generated during remedial activities.
Remediation Activities			
Technical Requirement - Standard for Capping and Plugging of Wells	16 TAC § 76.1004	Describes standards for capping and plugging wells that penetrate undesirable water or constituent zones.	ARAR applies to wells on the site that may need to be plugged during remedial activities.
Permit-by-rule for Air Emissions During Remedial Activities	30 TAC § 106	Requires employment of fugitive dust controls and meeting applicable standards for specific contaminants, as appropriate. Confirms compliance via air monitoring during excavation activities. Also applicable to emissions from remediation system. Equipment used to extract, handle, process, condition, reclaim, or destroy contaminants for the purpose of remediation is permitted by rule, provided that all the conditions of this section are satisfied.	ARAR applies because remedial activities may include emissions.
Visible and Particulate Emissions Standard	30 TAC § 111.145	Requires meeting visible emission standards using fugitive dust controls, such as wetting, and confirm compliance via air monitoring during excavation activities.	ARAR applies because possible remedial alternatives include excavation.
Edwards Aquifer Protection Program	30 TAC § 213	The purpose of this chapter is to regulate activities having the potential for polluting the Edwards Aquifer and hydrologically connected surface streams in order to protect existing and potential uses of ground water and maintain Texas Surface Water Quality Standards. The activities addressed are those that pose a threat to water quality.	ARAR applies to remedial activities performed on impacted ground water.

APPENDIX D
TENTATIVE DETERMINATION OF APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

ARAR	Citation (If Available)	Description	Applicability
Ground Water Wells/Water Discharge			
National Pollutant Discharge Elimination System	40 CFR 122, 40 CFR 125	Provides conditions that must be incorporated into NPDES permits. Applicable to discharge of storm water from the Site.	ARAR applies because water may be discharged from the site during remedial activities.
Underground Injection Control Program	40 CFR 144	Provides minimum requirements for Class 5 injection wells. Applicable to alternative where reagents will be injected below the water table.	ARAR applies because possible remedial alternative includes injecting amendments or treated ground water.
Pre-treatment Requirements for Discharge to POTW	30 TAC § 315	Requires water discharged to City POTW to meet specific allowable contaminant levels.	ARAR applies because extracted ground water treated with an ai stripper at the site may be delivered to POTWs.
Underground Injection Control Program	30 TAC § 331	Requires state approval for reinjection of treated ground water and any treatment amendments.	ARAR applies because possible remedial alternative may include insitu bioremediation and reinjection of treated ground water.
Texas Surface Water Quality Standards	30 TAC § 307	Establishes surface water limits to ensure public health and enjoyment, propagation and protection of terrestrial and aquatic life, operation of existing industries, and economic development of the state.	TBC - May be applicable if remedial actions result in discharge into adjacent surface water.
TPDES Construction General Permit	TXR150000	General permit to discharge water from construction activities.	ARAR applies because construction activities will be performed during remedial action at the site.

Notes:
ARAR - Applicable or relevant and appropriate requirements
CERCLA - Comprehensive Environmental Response, Compensation and Liabilities Act
CFR - Code of Federal Regulations
DOT - Department of Transportation
LDR - Land Disposal Restrictions
MCL - Maximum Contaminant Level
MCLg - Maximum Contaminant Level goal
NCP - National Contingency Plan
NPDES - National Pollutant Discharge Elimination System
OSHA - Occupational Safety and Health Administration
RCRA - Resource Conservation and Recovery Act
TAC - Texas Administrative Code
TBC - To be considered
TCEQ - Texas Commision on Environmental Quality
TCLP- Toxicity characteristic leaching procedure
TPDES - Texas Pollutant Discharge Elimination System
USC - United States Code